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Benedicite:

OR

THE SONG OF THE THREE CHILDREN.

BEING ILLUSTRATIONS OF THE POWER, WISDOM AND GOODNESS OF GOD, AS MANIFESTED IN HIS WORKS.

By G. CHAPLIN CHILD, M.D.

IN TWO VOLUMES—VOL. I.

London:
JOHN MURRAY, ALBEMARLE STREET,
1866.

138. g. 155.

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AFFECTIONATELY OFFERED

TO MY MOTHER

IN REMEMBRANCE OF HER

NINETY-FIFTH BIRTH-DAY.

MAY 14, 1866.

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"Every advance in our knowledge of the natural world will, if rightly directed by the spirit of true humility, and with a prayer for God's blessing, advance us in our knowledge of Himself, and will prepare us to receive His revelations of His Will with profounder reverence."

Sir ROBERT H. INGLIS, *British Association*, 1847.

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GOD MAGNIFIED IN HIS WORKS.

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GOD MAGNIFIED IN HIS WORKS.

Babylon—the glory of kingdoms, the beauty of the Chaldees' excellency!—ISAIAH xiii. 19.

Her cities are a desolation, a dry land, and a wilderness, a land wherein no man dwelleth.—JEREMIAH li. 43.

IN an outlying province of the Turkish empire, where sultan and firman are often superseded by the lawless will of sheik or pacha, two famous rivers—the Tigris and Euphrates—gradually converge, and, after mingling their waters together, glide gently onwards to the Persian gulph. In the fork thus formed between them stretches a vast plain, made known to us in early Scripture History as Shinar, Chaldæa, and Babylon, as well as by other less familiar names, but to which the term Mesopotamia has been more usually applied, as it aptly designates a district "lying between rivers." The general aspect of this plain is one of desolation. Fertile strips here

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and there border the Euphrates' banks, and willows are still seen flourishing where the sorrowing Israelites once hung up their harps; but away from those green fringes the eye wanders over wild, dreary wastes from which the last traces of cultivation are slowly dying out. Vast tracts lie soaked in permanent swamps, while much of the remaining land is, at one period of the year, flooded by the unheeded inundations of the neighbouring rivers, and, at another, baked into an arid desert by the burning rays of the sun. It need scarcely be said that population has almost disappeared from those melancholy plains; for the wandering Arab is little tempted to pitch his tent or to pasture his flocks on so sterile a soil. The doom that was so clearly foretold by the prophets has fallen upon it, and Babylon now "lies desolate in the sight of all that pass by." It has become the "habitation of the beasts of the desert." As the traveller plods onwards over its unfrequented tracts, the startled wild-fowl rises with quick splash from the reedy pool, or a few scared gazelles may perhaps be descried bounding over the distant plain. The "owl" and the "bittern", the jackal and the hyena add their testimony to the exactness with which the words of Scripture have been fulfilled. More rarely a solitary lion may be seen skulking among the strange, mysterious mounds and "heaps"

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of stones that loom here and there above the plain.

Mournful and dreary though this land now be, it is and ever will remain one of the most interesting spots on earth. It was not always "desolate." No other place, perhaps, claims with a better title to be regarded as the scene where our first parents walked together in paradise. Such, at least, has been the common tradition; and in a well-known edition of the Bible, published in 1599, may be found a map of the Garden of Eden, of which the site of Babylon forms the centre. But, be that as it may, there can be no doubt of its former greatness and fertility, for the record is plainly written all over the soil. Everywhere it is furrowed by ruined canals, of which some tell us of departed commerce and wealth, others of skilful irrigation and abundant crops. Heaps of rubbish are to be met with in which lie hidden fragments of pottery which bear witness to the former presence of a highly cultivated people; and uncouth mounds rise strangely above the plain, in which the last relics of palaces and cities are buried together. For centuries History appeared to have lost her hold upon those great places of the past, and it is only within the last few years that some of them have been rescued from the oblivion that was slowly creeping over them. Questioned by the light of modern

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knowledge those mysterious stones of the plains open up to us the first page in the history of nations —transport us back almost to the dawn where antiquity begins, and bring within our sight those to whom the deluge was a recent event. They impart a substance to scenes we have often tried in vain to realise. In imagination we see Nimrod, the Mighty Hunter, busy with the foundations of the city of Babel on the neighbouring Euphrates' bank, and piling up the "tower that was to reach to heaven." Then it was that the patriarchal dignity of early Bible records expanded into royalty, and Babylon became the starting point in the long pedigree of kingdoms.

Babylon touched the zenith of its grandeur two thousand four hundred and fifty years ago, when Nebuchadnezzar sat upon the throne. He was the great warrior of that age. After overrunning Egypt he had returned to his capital laden with its spoil; he had chastised his rebellious subjects and treacherous allies, and he had utterly crushed the power of the Kings of Judah. The wicked and faithless Jehoiakim, blind to the warnings he received, had brought a terrible doom upon his country; for Nebuchadnezzar, not content with plundering the treasures of the temple at Jerusalem, carried the king himself a prisoner to Babylon. Among the captives on this occasion were included

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Daniel the Prophet and his three friends—Ananias, Azarias and Misael, who in the land of their exile received the Chaldean names of Shadrach, Meshach, and Abednego.

Nebuchadnezzar was no less great in the arts of peace than in those of war. He, therefore, encouraged learned men to make his capital their resort, and he also promoted the national prosperity by favouring agriculture and commerce. He dug canals in all directions to fertilise the land by irrigation. His merchants traded along the rich shores of the Mediterranean, and penetrated even to remote China. He provided for the security of Babylon by building or strengthening its walls, and he made it beautiful by adorning it with palaces. Its "hanging-gardens" were acknowledged throughout ancient times to be one of the wonders of the world, and their fame has endured up to this very hour.

At the court of such a monarch, Daniel's learning was sure to procure for him distinction, and he soon became a member of the college of Magi or wise men. His subsequent success in interpreting Nebuchadnezzar's dream, after all others had failed, raised him to the first rank in the tyrant's favour, and we are told that "he sat in the gate of the king." Nor in his prosperity did he forget his three Jewish friends—Shadrach,

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Meshach, and Abednego—who through his influence were promoted to be Governors in the province of Babylon.

The history of Nebuchadnezzar and the burning, fiery furnace—so illustrative on the one hand of perfect trust in God, and, on the other, of God's power to deliver his servants from the assaults of their enemies—is endeared to all as one of the interesting Scripture narratives by which those who watched over us in the days of childhood endeavoured to attract us onwards to the knowledge of our Bible. In the book of Daniel it is related how Nebuchadnezzar, after having been brought by the miraculous interpretation of his dream to acknowledge the "God of Gods and Lord of Kings," subsequently relapsed into idolatry through the corrupting influence of worldly prosperity. In the full swell of his pride he set up a golden image, and commanded that all his subjects should fall down and worship it. The Babylonian nobles were jealous of the favour shown to the three captives; and they, therefore, encouraged this wicked fancy of the king, because it seemed to open out the means of effecting their ruin. They rightly calculated that the Hebrew Governors would never forsake the God of their Fathers, nor worship the image which the king had set up. And we know that when the hour of trial did come, Shadrach,

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Meshach, and Abednego remained true to their faith; and were forthwith bound and cast into the burning, fiery furnace, as a punishment for their disobedience to the tyrant's will.

From the torments and dangers of this ordeal the Three Hebrews were miraculously preserved. Daniel tells us that Nebuchadnezzar himself saw them "loose and walking in the midst of the fire." "Not a hair of their heads was singed, neither were their coats changed, nor had the smell of fire passed on them." Elsewhere, in the Song of the Three Children, we are told that "they walked in the midst of the fire, praising God, and blessing the Lord." After so signal a deliverance, it is easy to conceive the fervour with which their Hymn of gratitude was poured forth. The deepest consciousness of the merciful Power of God welled up in their hearts and burst from their lips, and the whole universe was ransacked for illustrations to typify and express it. In whatever direction they turned, they beheld nature crowded with emblems of His Greatness and Mercy, and they eagerly seized upon them as aids to bring their thoughts up to the fervour of their adoration. Shall not we also do wisely to profit by their example? Our daily obligations to God may not be so miraculous, in the ordinary meaning of the term, but they are, nevertheless, great and countless beyond

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our power to conceive. Let us then, in humble consciousness of the poverty and imperfection of our thanksgivings, gladly make this suggestive hymn our own, and let us on this, as on all occasions, accept with joy every aid that helps us to "bless, praise, and magnify the Lord."

Benedicite, omnia opera.

O ALL ye Works of the Lord, bless ye the Lord : praise him, and magnify him for ever.

O ye Angels of the Lord, bless ye the Lord : praise him, and magnify him for ever.

O ye Heavens, bless ye the Lord : praise him, and magnify him for ever.

O ye Waters that be above the Firmament, bless ye the Lord : praise him, and magnify him for ever.

O all ye Powers of the Lord, bless ye the Lord : praise him, and magnify him for ever.

O ye Sun, and Moon, bless ye the Lord : praise him, and magnify him for ever.

O ye Stars of Heaven, bless ye the Lord : praise him, and magnify him for ever.

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O ye Showers, and Dew, bless ye the Lord : praise him, and magnify him for ever.

O ye Winds of God, bless ye the Lord : praise him, and magnify him for ever.

O ye Fire and Heat, bless ye the Lord : praise him, and magnify him for ever.

O ye Winter and Summer, bless ye the Lord : praise him, and magnify him for ever.

O ye Dews, and Frosts, bless ye the Lord : praise him, and magnify him for ever.

O ye Frost and Cold, bless ye the Lord : praise him, and magnify him for ever.

O ye Ice and Snow, bless ye the Lord : praise him, and magnify him for ever.

O ye Nights, and Days, bless ye the Lord : praise him, and magnify him for ever.

O ye Light and Darkness, bless ye the Lord : praise him, and magnify him for ever.

O ye Lightnings, and Clouds, bless ye the Lord : praise him, and magnify him for ever.

O let the Earth bless the Lord : yea, let it praise him, and magnify him for ever.

O ye Mountains, and Hills, bless ye the Lord : praise him, and magnify him for ever.

O all ye Green Things upon the Earth, bless ye the Lord : praise him, and magnify him for ever.

O ye Wells, bless ye the Lord : praise him, and magnify him for ever.

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O ye Seas, and Floods, bless ye the Lord : praise him, and magnify him for ever.

O ye Whales, and all that move in the Waters, bless ye the Lord : praise him, and magnify him for ever.

O all ye Fowls of the Air, bless ye the Lord : praise him, and magnify him for ever.

O all ye Beasts, and Cattle, bless ye the Lord : praise him, and magnify him for ever.

O ye Children of Men, bless ye the Lord : praise him, and magnify him for ever.

O let Israel bless the Lord : praise him, and magnify him for ever.

O ye Priests of the Lord, bless ye the Lord : praise him, and magnify him for ever.

O ye Servants of the Lord, bless ye the Lord : praise him, and magnify him for ever.

O ye Spirits and Souls of the Righteous, bless ye the Lord : praise him, and magnify him for ever.

O ye holy and humble Men of heart, bless ye the Lord : praise him, and magnify him for ever.

O Ananias, Azarias, and Misael, bless ye the Lord : praise him, and magnify him for ever.

Glory be to the Father, and to the Son : and to the Holy Ghost ;

As it was in the beginning, is now, and ever shall be : world without end. Amen.

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The "Benedicite" forms a part of The Song of The Three Children, with whom tradition has identified Shadrach, Meshach, and Abednego. But, whether tradition be right or wrong in this instance, the Canticle has an intrinsic interest of its own, both because it has been incorporated with the Service of the Church, and because it is one of the most suggestive and soul-stirring hymns in existence. In accordance with an injunction in King Edward the Sixth's First Book, it is customary to sing the "Benedicite" during Lent, and in some churches, we regret to think, it is never heard at any other time, while in a few it seems to be banished from the Service altogether. It is also true that Books of Common Prayer have been published in which this hymn finds no place. It is impossible, indeed, not to perceive that there is a "shyness" or even a repugnance with some in regard to it, which causes it to be sung at the times prescribed rather in obedience to custom or ecclesiastical authority, than from any feeling of its fitness for devotional use. And yet, as it cannot be denied that many find in it a valued help to adoration, the conviction rises strongly in the mind that it is equally fitted to become an aid to all. Whence comes, let us ask, this difference in the effect produced by the same thing—whence this absence of appreciation which spoils

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and renders distasteful to some a hymn from which others derive such heart-felt benefit? May not the cause lie either in a too literal acceptance of the words themselves, or in the want of those few grains of knowledge which alone were needed to bring home to us the force of the hymn as an exposition of the Power and Mercy of God. When sculptors and painters represent animals bellowing forth their praise from gaping mouths, they embody the literal meaning of the words, and give currency to that erroneous conception of their import which, with more or less distinctness, has found an entrance into the minds of many. It seems almost needless to remark that such a gross realisation of the hymn misses its purpose altogether. The "beasts that perish" have no knowledge of their Creator, and are not susceptible of those emotions which constitute adoration; while man is even less nobly distinguished from them by his form than he is by his moral nature, and his privilege of enjoying the perception of God and singing His praise. A literal interpretation given to the "Benedicite" clothes it with inconsistency, suggests an Æsopian fable rather than a Christian hymn, and tends to check rather than promote devotion. Every shade of such a meaning must be banished from the mind, and exchanged for another more true and elevating. It is only by the thoughts

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suggested by the wonderful perfections of animals that they can serve as aids to adoration; and it is in the same sense only that dead things—such as stars, the sea, or the wind—can be properly associated with living things as promoting with equal fitness the same end. If this interpretation be not admitted the words degenerate into extravagance, and are stripped of all their beautiful significance in the minds of thoughtful men. Invested with the same indirect meaning, the names of Ananias, Azarias, and Misael are most fitly introduced among the invocations of the hymn. They have, it is true, long passed from the scene of their trials; but, though no voice of praise may rise from the grave, their memories remain to us as symbols of God's mercy and power. In thinking of them we recal the example of men who trusted in the Lord and were not forsaken—who were ready to brave the most cruel death rather than deny their faith—and whom no tyrant could either terrify or hurt, because they were upheld by God's protection. Is there no aid to devotion in such examples, or in the thoughts that rise up in association with such names? On the contrary, no invocation in the hymn is more profitable or suggestive. Thus, by their trusting faith when living, they continue, even though dead, to praise and magnify "the power of the Lord for ever."

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Though all are ready with the general admission that everything in nature exhibits the Power and Goodness of God, it will not be denied that a little knowledge of the way in which these are displayed would give additional distinctness to the feeling. Such knowledge, indeed, will often serve to change what is merely a tame and passive acquiescence into a fervent sentiment of adoration founded on conviction and experience. Now, if there be any truth in this remark, it is surely well worth while to turn our attention to such subjects. Physical Science and Natural History liberally reward their votaries, for every onward step is fraught with pleasure, and brings an immediate reward in the interest with which it invests the common things around us. Many of their most elevating secrets are to be learnt without that preliminary drudgery which besets the portals of some other sciences: and an amount of knowledge, so moderate as to be within the reach of everybody, is all that is required to open out to us a clear view of those proofs of Power and Goodness which cluster round the verses of the "Benedicite."

It need scarcely be remarked, however, that knowledge of this kind is not to be acquired in church, but by previous preparation at home and in our walks. The offering up of praise within the

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sanctuary exacts our whole mind and our whole heart, and our thoughts at such moments must not be encouraged to wander away in search of illustrations of the truths we are uttering. Experience will soon bring to us the welcome proof that the thoughtful consideration of God's works which is based upon a knowledge of their nature and of the Power and Goodness they display, creates a condition of mind so impressible that every solemn allusion to them instantly and without conscious effort raises feelings of adoration in unison with the subject. The details of the wonderful perfections by which these feelings were originally developed may be absent, or even forgotten, but the deep devotional impress with which they once imbued the understanding never fades away. They who have acquired this sensibility to those hymns of praise which are ever ascending from all God's works around, have found an aid to adoration, the value of which is known and thankfully acknowledged by themselves, but which must sometimes appear like extravagance or affectation to others who have never taken any pains to cherish it. It is only by such means that our sentiments can be brought into full harmony with the spirit of the Hymn. But when the words of the "Benedicite" fall upon ears thus prepared by the understanding and the heart, they speak the clearest language,

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and stand forth as the emblems of Power, Wisdom, and Goodness.

All thy works praise Thee, O Lord.—Ps. cxlv.

Of the fitness of the natural objects around us to awaken feelings of devotion there can be no doubt. All things are wonderfully made and wonderfully adjusted to each other; and we alone, among created beings, have been endowed with faculties enabling us to recognise the perfections they exhibit, on purpose that we might praise God by the feelings they rouse within us. The Psalms of David are filled with beautiful illustrations to show how natural objects serve as aids to adoration, and it may be safely asserted that a Book of Praise was never yet written in which they were not thus used. If there be any sceptic who believes not in this power, let him make trial. Experience will soon convert him, and draw an answer of thankful consciousness from his own heart.

The object of this book is to offer a series of illustrations of the Beneficence and Greatness of God, as they are suggested to our minds by the words of the "Benedicite." A few of the verses, it will be noticed, are omitted, not because they are inapplicable to devotion, but because they do not come within range of that kind of illustration

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to which I have thought it proper to confine myself. But, within this limitation, enough and more than enough remains for the work on hand. It may, indeed, be truly said that he who undertakes to select from the many fields of nature the most striking examples of God's Providence will find his chief difficulty to arise from the "embarrassment of riches." He is like a man wandering in a gallery where all is truth and perfection, and who has rashly engaged to single out that only which is preeminently the best. A feeling of this kind weighs on me now, for, while illustrations abound on every side, I fear lest I should select some examples where others ought to have been preferred,—not because they were more wonderful or more perfect, but because they were better adapted for the purpose here intended. Let me hasten to disclaim all pretension to instruct the learned or the scientific. It becomes me here rather to acknowledge with gratitude my own obligations to them. It would, indeed, be difficult to treat satisfactorily of the various matters contained in this book without seeking to profit by the labours of the Herschels, Whewell, Maury, Guillemin, Lardner, Owen, Darwin, and many others whose names are well known as the authors of standard works. I know beforehand that the subject, for its own sake, will be received with sympathy by those whose delight it

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is ever to be on the outlook for the suggestion of trains of thought which lead them to magnify God in His Works; but it would be even more gratifying to me if I should succeed in awakening an interest in the "Benedicite" in some who, perhaps, may not have hitherto considered the objects therein invoked under the aspect here given to them. Soon will they make the precious discovery that they cannot add a line to their knowledge of the natural objects around them without at the same time adding to the distinctness of the feeling with which they join in the words of the Hymn.

While endeavouring to illustrate the effect of a little knowledge in developing that sensitiveness to the divine Power and Mercy which, while it softens the heart, beckons us onwards to that worship which springs from the contemplation of natural objects, I wish carefully to guard against every appearance of desiring to elevate this means above its proper place. We are here dealing with the things that belong to the kingdom of nature, and not with those pertaining to the kingdom of grace; and, if need be, it must often be recalled that how praiseworthy soever this meditative worship may be, it can never supersede, and must always be subordinate to, those higher motives for worship which are unfolded in the

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doctrines of Christianity. The one is essential and must be done; while all that can be said of the other is that it is both fitting and profitable, and ought not to be left undone. God has graciously endowed us with faculties to comprehend His Works, and with every new appreciation of His design we seem to be taken more and more into His confidence. Shall we then neglect or throw away this inestimable privilege, or can we ever hope to employ our talents in a nobler or more elevating purpose? Experience will prove that God blesses our efforts to trace out the perfection of His Works with an immediate reward, for the pursuit is replete with rational pleasure no less than with moral improvement.

O praise the Lord with me, let us magnify His Name together. Ps. xxxiv.

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THE HEAVENS.

O ye Heavens, bless ye the Lord; praise Him, and magnify Him for ever.

AMONG all the sights the eye can look upon nothing is comparable to the Heavens for the sentiment with which they charm the mind. The language they speak comes to us from remote, mysterious worlds; but, though it may be imperfectly understood, it is at least universally felt. The great and the little—the civilized man and the savage, the philosopher and the rustic—all feel their influence, and are from time to time irresistibly drawn towards them by mingled emotions of admiration, gratitude, and awe, such as none of the other features of nature can excite in an equal degree. No wonder, therefore, that the Three Children, intent on calling up every image by which God's Goodness to men and their dependence on Him could be depicted, should first of all turn to-

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wards the Heavens. Again and again the grand features of the firmament are passed in review, and invoked with fervour. In the eager intensity of their feelings order and method are but little regarded, and they pour forth their thoughts in song as these come welling up in their minds. So may it happily sometimes be with ourselves; and in those moments when we too are drawn with desire to "bless, praise, and magnify the Lord" for the visible works of Creation, we shall surely find that the Heavens suggest to our conception the grandest symbols of His power and goodness.

So strongly, however, is the idea of the "incomprehensible" associated by many with the mysteries of the firmament, that they are habitually prone to regard the teachings of astronomers as little else than scientific guess-work. Nevertheless, the best intellects in all countries assure us, and demonstrate before our eyes, that, within certain limits, astronomy is the most exact and perfect of sciences, and that, even when it deals with distances and magnitudes which are practically inconceivable, its conclusions, though often claiming to be approximative only, have yet no affinity whatever with guess-work. Let such sceptics think of the certainty with which sidereal events are predicted beforehand. Let them reflect on the evidence of the most exact knowledge of the heavenly bodies involved in the

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calculation of eclipses, in fixing the very moment when the moon's dark outline shall begin to creep over the sun's bright disk, or in predicting the instant when a planet's light shall be extinguished behind our satellite. How wonderful the tracking of a comet's wanderings—millions of miles beyond the far off region of Uranus, and foretelling the time of its return after long years of absence! Do not these, and a thousand other equally wonderful feats, attest both the soundness of the principles on which the astronomer works, and the reasonableness of receiving his assurances with trust, even though it may be impossible for more than a few gifted minds to follow the calculations on which they are based?

Did any of our readers ever happen to bestow a glance upon the Nautical Almanack? It is published by the considerate Government of our country at a very cheap rate, in order to facilitate its entrance into the cabin of every seagoing ship. Ostensibly it is a voluminous collection of dry figures and curious signs running on interminably page after page; but, in reality, it is a yearly record of the soundness of the teachings of Astronomy, and of the blessings they bring to man. Eclipses of the sun and moon, of Jupiter's satellites, sidereal positions and distances, and a multitude of other heavenly events and matters of the last importance

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to navigation, are there foretold with the most rigid exactness. Every single figure and every single sign represents an important sidereal fact, and is charged with a message from the skies for our guidance. On the trackless ocean this book is the mariner's trusted friend and counsellor, and daily and nightly its revelations bring safety to ships in all parts of the world. The acquisition of such rare and precious knowledge—this mapping out beforehand, almost to a hairbreadth, the exact order and track in which the heavenly bodies will run their course through space, and the precise relative position they will occupy at any given moment when they can be seen in any part of the world—is a fact which, if applicable to the current year only, might well fill us with astonishment. But it becomes infinitely more marvellous when we reflect that the Nautical Almanack is regularly published three or four years in advance, in order that the mariner, during the most distant voyages which commerce can exact, may never be without his faithful monitor. It is truly something more than a mere book—it is an emblem of the Power and Order of the Creator in the government of the Heavens, and a monument of the extent to which His creatures are privileged to unravel the laws of the Universe!

The year 1846 will ever be memorable for having witnessed one of the most striking illustrations of

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the truth of Astronomy. Few can have forgotten the astonishment with which the discovery of the planet Neptune was then received, or the fact that it was due not to a lucky or accidental pointing of the telescope towards a particular quarter of the heavens, but to positive calculations worked out in the closet; thus proving that, before the planet was seen by the eye, it had been already grasped by the mind. The history of its finding was a triumph of human intellect. The distant Uranus—a planet hitherto orderly and correct—begins to show unusual movements in its orbit. It is, somehow, not exactly in the spot where according to the best calculations it ought to have been, and the whole astronomical world is thrown into perplexity. Two mathematicians, as yet but little known to fame, living far apart in different countries and acting independently of each other, concentrate the force of their penetrating intellects to find out the cause. The most obvious way of accounting for the event was to have inferred that some error in previous computations had occurred; and, in a matter so difficult, so abstruse, and so far off, what could have been more probable or more pardonable? But these astronomers, knew that the laws of gravity were fixed and sure, and that figures truly based on them could not deceive. By profound calculations each arrives at the conclusion that

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nothing can account for the "perturbation" except the disturbing influence of some hitherto unknown mass of matter exerting its attraction in a certain quarter of the Heavens. So implicit, so undoubting is the faith of Leverrier in the truth of his deductions, that he requests a brother astronomer in Berlin to look out for this mass at a special point in space on a particular night; and there, sure enough, the disturber immediately discloses himself, and soon shews his title to be admitted into the steady and orderly rank of his fellow-planets. The coincidence of two astronomers, Leverrier and our countryman Adams, arriving at this discovery through the agency of figures based on physical observation, precludes every idea of guess-work; while such was the agreement between their final deductions that the point of the Heavens fixed upon by both as the spot where the disturber lay was almost identical. "Such a discovery" says Arago "is one of the most brilliant manifestations of the exactitude of the system of modern Astronomers."

As the Heavens have irresistibly attracted the attention of mankind in all ages, Astronomy naturally came to be the Father of sciences, and it was from remotest times cultivated with considerable success by the Chaldeans on the plains of Mesopotamia. Doubtless the Three Hebrews at Nebuchadnezzar's court were well versed in the science

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of their day, but, whatever the amount of that knowledge might have been, it must have been extremely imperfect when measured by modern standards. Comparatively speaking they knew but little of the grandeur of the Heavens; and yet that little amply sufficed to point with its imagery the fervour of their worship. Since then, by God's blessing, the range of Astronomy has been widened, its views soar higher and probe deeper, its truths are better comprehended, its marvellous adjustments have been analysed and traced more clearly upon the understanding. Shall we, then, with our better knowledge, find less aid in it to rouse our adoration than did the Three Children of old, and shall the more perfect view of the Heavens now vouchsafed to us fall cold and resultless upon our hearts? If this, indeed, be the case, are we not treating with neglect an aid to adoration which God himself has spread out before our eyes, and are we not in some degree frustrating that purpose of praise and glorification for which both they and we were created?

Astronomy is without question the grandest of sciences. It deals with masses, distances, and velocities which in their immensity belong specially to itself alone, and of which the mere conception transcends the utmost stretch of our finite faculties. In no other branch of science is the limited grasp

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of our intellect more forcibly brought home to us. Yet, though baffled in the effort to rise to the level of its requirements, our strivings are by no means profitless. Is it not truly a precious privilege to be able to trace, imperfectly though it may be, the hand of the All-mighty Architect in these his grandest works, and to obtain by this means a broader consciousness of his Omnipotence? In raising our wonder and admiration other sciences need the help of details and expositions, but in Astronomy the mere enunciation of a few measurements suffices to elevate our ideas of His Power to the highest point to which man's finite faculties can carry them.

The expence of suitable instruments, the preliminary study, the persevering patience, and the long night vigils that are necessary will probably always prevent the higher walks of scientific Astronomy from becoming a popular pursuit; nevertheless, we earnestly recommend all who can to seize every opportunity that may fall in their way of having a thoughtful look at the Heavens through a good telescope. Their reward will be immediate. Even were they to take their peep with feelings not more elevated than those with which folks at a fair look at a raree show, the glance would bring some profit; but, if they be prepared beforehand with their "few grains of knowledge," how useful and

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improving the survey becomes. The first look at the Heavens through a good telescope forms an epoch in our life. Our faith in the realities of Astronomy passes with sudden bound from theory into practice; planets and stars become henceforth distinct and solid existences in our minds; our doubts vanish, and our belief settles into conviction. We behold the mysterious Moon of our childhood mapped into brilliant mountain-peaks, and dark precipices, and softly lighted plains; we see Jupiter shining like another fair Luna, with attendant satellites moving round him in their well-known paths; or we turn with admiration to Saturn encircled by his famous ring, with outlines as distinct as if that glorious creation lay but a few miles off. Perhaps we may behold the beauteous Venus shining with resplendent circular disk, or curiously passing through her many phases in mimic rivalry of the moon. Or, leaving these near neighbours far behind, we may penetrate more deeply into space, and mark how the brightest flashing stars are reduced to a small, round, unmagnifiable point. A few evening explorations in propitious weather will suffice to grave all these objects and many other precious recollections in our minds for ever. Then is realised, better than at any previous moment of our existence, the power of the Lord of Creation.

While Astronomy, beyond all other sciences,

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thus lifts up man's conception of God's glory as displayed in his works, it is no less calculated to bring home to him the "littleness" of his own world amid the great creations of the Universe. The stupendous truths at which the finger of astronomy is ever pointing ought to keep uppermost in his heart the wholesome lessons of humility. Well may the oft-told interjection rise to his lips, Lord, what is man that Thou art mindful of him! Such thoughts, indeed, bring with them both humility and exultation. Man's habitation is in very truth a mere speck in the Universe, dwarfed and thrown into the shade by nearly all the worlds around it, and he himself is a mere atom creeping through his brief existence upon its surface. His high place in Creation is won by the loftiness of his moral nature, and, above all, by the destiny that awaits him. Apart from this revelation, man and his earth are but a grain of dust among the myriads of worlds that people the infinity of space.

Therefore shall every good man sing of thy praise without ceasing. Ps. xxx.

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SUN AND MOON.

O ye Sun and Moon, bless ye the Lord; praise Him, and magnify Him for ever.

THERE are not a few in this world who habitually receive God's blessings so much as a matter of course that they are scarcely conscious of any active feeling of gratitude in regard to them. The very regularity and profusion with which these blessings are showered on all alike seems to have the effect of deadening the sense of individual obligation. A general admission of thankfulness may occasionally be made at church or in the closet, but there is a want of that abiding consciousness of it with which we ought to be imbued, as well as of that frequent pondering upon details which, by illustrating the dependence of every creature upon God, causes the heart to swell with grateful adoration. Such thoughts never fail to improve our moral nature

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by bringing the truth home to us more and more that we are indeed God's children.

It would be no easy task for a thankful mind to sum up all the blessings diffused over our planet by the sun. It is the mainspring of animated nature. Without its genial rays the present system of the earth's government could not endure, and life itself would soon disappear from the globe. To it we are indebted for light and warmth—the twin stimulants of vital force—for our food and clothing, for our busy days and rest-bringing nights, for months and years, and happy alternations of the seasons. Its rays, in short, are intertwined with all our wants and comforts; they gladden the eye and cheer the heart.

I will praise the name of God with a song, and magnify it with thanksgiving.—Ps. lxix.

The sun is the central pivot of the solar system, and round it the Earth and all the other planets keep whirling in elliptical orbits. Its power and influence—its light, heat, and attraction—reach through a domain in space which it would require a line of more than 6000 millions of miles to span. With the greater part of this wide field astronomers are familiar, and it may be truly said that scarcely a man knows the roads of his own parish with more exactness than they do the high-

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ways of the skies. Not only can they map out to a nicety the paths of the planets careering through it like islands floating in a sea of ether, but they can look backwards and tell the exact spot where each globe was at any moment of the remote past, or forwards, and point to the place where each will be found at any given moment of the remote future.

What is the mighty power which thus maintains such order in the Heavens, which steadies the planets in their orbits, and traces out for them a route so wisely planned as to avoid all chances of collision? Two antagonistic forces—gravitation or attraction, combined with a centrifugal impulse—accomplish the wonderful task. To these faithful servants, which know neither fatigue nor slumber, God commits the safety of the Universe. Let us in imagination glance back to that far-off time when "in the beginning the Heavens and the Earth were created." Matter having been prepared sufficient, it may be, for the vast requirements of the solar system, every particle of it was endowed with the property of mutual attraction, and the force of this attraction was fixed so as to act in a certain proportion to mass and distance. In other words, the law then impressed on matter was, that attraction should increase according to mass, and diminish according to the square of the distance.

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The matter of the solar system may have been created in separate portions, or it may have been divided into separate portions corresponding to the size of the different planets; after which, the particles of each planet, being as yet mobile, arranged themselves in obedience to their mutual attraction into globes, just as we see the mobile particles of water coalesce into a drop, or as quicksilver runs into globules. The sun was placed in the centre, and became the pivot of the whole system, tying to itself the different planets by the cord of its superior attraction. In accordance with the law just mentioned, this loadstone power of the sun was the inevitable result of its superior mass.

It is obvious that in whatever corner of the sun's domain the planets had been placed, the searching power of his attraction would have found them out, and would inevitably have destroyed them by dragging them in upon himself, had this tendency not been counteracted by some other influence. Another force, therefore, was established — the centrifugal. The Great Architect, "weighing in his hand," as the Psalmist figuratively, and yet almost literally expresses it, the mass of each orb, projected it on its course through space with exactly that force and at exactly that angle which was needed to counterbalance the attractive power of the sun; and the obedient globe, thus

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seized upon by the two balanced forces, was compelled to move onwards in a path representing the diagonal between both. And as these forces are permanent, the movements of the earth and of the other planets must be permanent also; nor can anything stop the working of this most perfect machine except the Word which created it.

The voice of the Lord is mighty in operation.—Ps. xxix.

How shall we mentally gauge the distance or estimate the size of the master-centre which thus holds all the planets in his grasp? The immensity of both confounds our efforts. When we are told that the sun is separated from us by a chasm of nearly 92 millions of miles, that its diameter is 850,000 miles, and its circumference about 2,671,000 miles, we can realise nothing beyond a vague idea of vastness, and we are forced to look round for other standards to help our laggard faculties. From the comparatively small size of his disk when viewed from the earth, we catch the idea how enormous that distance must be which is able thus to dwarf it down. It is 384 times as far off as the moon. A cannon-ball fired from the earth and keeping up its velocity, would not reach it in less than 22 years. "A railway train," Brayley observes, "at the average speed of thirty miles an hour, continuously maintained, would arrive at the moon

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in eleven months, but would not reach the sun in less than about 352 years; so that if such a train had been started in the year 1512, the 3rd year of the reign of Henry VIII., it would only have reached the sun in 1864."

The sun's diameter is equally astounding. It exceeds by 107 times the mean diameter of the earth. It is nearly four times greater than the radius of the moon's orbit round the earth; so that if the earth were placed in the centre of the sun, the moon's orbit, so far from extending to the circumference of the sun, would scarcely reach to within 187,000 miles of its surface. The locomotive just mentioned, on its arrival at the sun, "would be rather more than a year and a half in reaching the sun's centre, three years and a half in passing across the sun, supposing it were tunnelled through, and ten years and one eighth in going round it." "Now the same train would attain the centre of the earth in five days and a half, pass through it in eleven days, and go round it in thirty-seven days." The bulk of the sun is not less than 600 times as great as that of all the planets put together; and it would take 1,405,000 Earths to make a globe of equal magnitude.

Great difference of opinion prevails among astronomers respecting the physical condition of the sun, and both its surface and encircling atmospheres

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are full of mysterious grandeur. Still, although not so well-known as the planets, many points of interest have been partially made out. Its surface is much more rugged than that of our planet, with heights and clefts somewhat on the scale of its vast magnitude. A mountain in the sun, however, in order to bear the same proportion to it as our highest Himalayan peaks do to our earth, would require to attain an altitude of 600 miles: now none of its mountains have been estimated at more than 200 miles high. The mountains on the earth have been compared to the inequalities upon the rind of an orange, while those of the sun would in their proportion more resemble the tubercles of a pine-apple.

Most astronomers consider the sun to be an incandescent body encircled by two atmospheres. Its temperature probably varies in the different parts of its immensity, but, where most intense, it appears to transcend anything we can conceive. Like the distances and velocities and nearly all else that relates to the heavenly orbs, the degree of the sun's heat overtasks our power to imagine, and we should require for its comprehension some new standard of measurement. The minimum of solar temperature, indeed, seems to begin far above the point where terrestrial temperature leaves off. According to one philosopher the heat is "seven times

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as great as that of the vivid ignition of the fuel in the strongest blast furnace;" while another, after a careful series of experiments, estimates it at nearly 13 millions of degrees of Fahrenheit! To aid us in appreciating this temperature, or rather to show us how impossible it is for us even to conceive it, it may be borne in mind that cast-iron requires for fusion a heat which amounts only to 2786 degrees, and that the oxy-hydrogen flame—one of the hottest known—does not much exceed 14000° Fahrenheit, which is scarcely one-thousandth part of the temperature here ascribed to the sun.

Of the two atmospheres encircling the sun, that which is nearest its surface is considered to be non-luminous, while the other floats upon it and forms the "photosphere" which we see in looking at the sun's bright disk. From this photosphere, as well as, probably, from the surface of the sun itself, are radiated the heat and light which are to vivify the planets of the solar system. Flame-like masses—some computed to be 150,000 miles in length—are piled upon or overlap each other, and sweep onwards in constant agitation, like mountain-billows of living fire. Although the light afforded by this furnace pales that of every other luminary, its amount has been approximately ascertained, for the purpose, as we shall soon see, of serving as a standard to astronomers when estimating the dis-

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tances of the stars by means of the light they evolve. Thus Wollaston calculated that 20 millions of stars as bright as Sirius, or rather more than 800 thousand full moons, would be required in order to shed upon the earth an illumination equal to that of the sun. Another estimate makes sunlight equal to 5570 wax candles held at a distance of only one foot from an object.

Let us now turn our back upon the sun, which for the sake of comparison may be represented by a globe two feet in diameter, and let us in imagination wing our way across the space filled by the solar system. A short flight of 37 millions of miles brings us to a world which, compared with the two-feet globe, is no bigger than a grain of mustard-seed, while it is so bathed in the sun's dazzling rays that it is not easily distinguished when viewed from our earth. This fussy little planet whirls round the sun at the tremendous pace of a hundred thousand miles an hour, by which he proves his title to be called Mercury, the "swift-footed" of mythology. The sun being so near attracts it with prodigious force, and to counteract this destructive tendency a corresponding centrifugal impulse was absolutely needed. From the strength of these two antagonistic forces its great velocity naturally results. The adjustment is perfect. At a distance of 68 millions of miles from

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the sun we behold Venus, the brightest and most dazzling of the heavenly hosts. In comparative size, she may be represented by a pea. She is our nearest neighbour among the planets, and the conditions under which she exists recall many of those amid which we ourselves live.

About 92 millions of miles from the sun we come upon another "pea," a trifle larger than the one representing Venus, and in it we hail our old familiar mother Earth. Here we shall not now linger, but passing onwards some 50 millions of miles we are attracted by the well-known ruddy glow of Mars,—an appearance which may depend either on the refraction of light in its atmosphere, resembling what we ourselves often see at sunset, or on the prevailing colour of its soil, which may be as highly tinted as our "old red sandstone." The comparative size is that of a pin's head. Mars is a planet that has lived down a very bad character. For ages every star-poet, astrologer, and almanack-maker had an ill word to say about him, and all sorts of evil things, including "manslaughter, byrnings of houses and warres," were ascribed to his cross nature. But truth has at length prevailed, and he is now established as an orderly member of the solar company. His mean orbital speed is 54 thousand miles an hour—nearly our own pace—but, as he takes twice as much time to run round

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the sun as we do, his year is consequently twice as long. Casting a glance behind we are reminded of the distance that now separates us from the sun by the perceptible waning of his light.

We next spread our wings for a very long flight. In passing through the "asteroid" zone of solar space, about 260 millions of miles from the sun, we may chance to fall in with some worlds so small that a locomotive could travel round them in a few hours. We know not very much about them except that their ways are eccentric and mysterious. They want the smooth round outline of the old planets. Their rugged and fragmentary aspect suggests that they may be the mere ruins of some mighty parent-planet, shattered into pieces by the Word of the Architect, and skilfully stowed away in space, so as to harmonize with the nice balancings of the solar system.

At length the shores of huge Jupiter are reached at a distance of nearly 500 millions of miles from the sun. To carry on the comparison, he is a "small orange" to the "pea" of our earth, or to the two-feet globe that represents the sun. His orbit is a path 3000 millions of miles long, which he accomplishes in an "annual" period of nearly 12 of our years. The sun's light has now shrunk considerably, but four brilliant moons or satellites, one or more of which are always "full,"

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help to afford some compensation. These moons, distant though they be from our earth, are not without their use to man, and there is hardly a well-informed mariner that leaves our shores who cannot occasionally turn them to account in settling his position at sea. The principle is extremely simple. The exact moment when one of these moons is eclipsed behind Jupiter's disk has to be noted, by chronometer rated to Greenwich time, and by a reference to the Nautical Almanack it may be compared with the hour at which the same event is timed for Greenwich. The difference in time will give the longitude, 4 minutes being allowed for each degree. If the eclipse be in advance of Greenwich time, the ship is to the east of that place; and to the west of it in the contrary case. Thus the good Lord has combined the lighting up of this far-off planet with a blessing to the inhabitants of our earth.

Before we arrive at Saturn, in our "outward-bound" course, we have to pass through a space nearly equal to the distance of Jupiter from the sun. We are now more than 900 millions of miles distant from the central pivot. Saturn's comparative size may be represented by an orange considerably smaller than the last. His year swallows up almost thirty of our own. The sun, though hardly giving one-ninetieth part of the light which we receive, is

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still equal to 3000 full moons, and is at least sufficient for vision, and all the necessary purposes of life. No fewer than eight satellites supplement the waning sunlight, besides a mysterious luminous "ring" of vast proportions.

Twice as far away from the sun as Saturn, Uranus, represented by a cherry, plods his weary way. Although he has a real diameter of 35,000 miles, he is rarely to be seen from the Earth by the naked eye. His annual journey round the sun is 10,000 millions of miles, and he consumes what we should consider a lifetime—84 years—in getting over it. His nights are lighted up by at least four moons that are known, but several others probably exist. The illumination received from the sun even here is equal to several hundred moons. Our little earth has now faded out of sight.

Only a few years ago Uranus was the last planetary station of our system, but the discovery of Neptune in 1846 gave us another resting-place on the long journey into space. Here, at a distance of 2862 millions of miles from the sun, we may pause awhile before entering upon the more remote exploration of the starry universe. We are approaching the frontier regions of our system, and the sun's light and the power of his attraction are gradually passing away. Between the shores of our sun-system and the shores of the

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nearest star-system lies a vast, mysterious chasm, in the adjacent recesses of which may still lurk some undiscovered planets, but into which, so far as we yet know, the wandering comets alone plunge deeply. We stand on the frontier of the sun's domain, and we are in imagination looking across one of those broad gulfs which, like impassable ramparts, fence off the different systems of the Universe from each other. It seemed needful that the Great Architect should interpose some such barrier between the contending attractions of the giant masses of matter scattered through space —that there should be a sea of limitation in which forces whose action might disturb each other should die out and be extinguished. In it the light-flood of our glorious sun gets weaker and weaker, and its bright disk wastes away by distance until it shines no bigger than a twinkling star. And the strong chain of its attraction which held with firm grasp the planets in their orbits, after dwindling by fixed degrees into a force that would not break a gossamer, is finally dissipated and lost.

It has been already stated that the earth and its fellow-planets are kept steady in their orbits by the exact adjustment of centrifugal and centripetal forces. They are in the position of the stone whirled round in a sling. If let go from the centre, they would fly off into space; if sur-

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rendered to the sole influence of the sun's attraction, they would inevitably be dragged into the vortex of its flames. As a curiosity in astronomy, calculations have been made to show the time which each planet would require for its fall into the sun. Thus it appears that while Mercury, the nearest, would require a fortnight, Uranus, at a distance of 1820 millions of miles, would be nearly 15 years in falling; while our earth would take 64½ days before it crashed into the sun.

Such calculations, however, have not always had a merely speculative interest. There was a time, not so very remote, when the possibility, or rather the certainty, of our earth dashing headlong into the sun seemed to be only too well established. Weak minds were terrified, and even the soundest astronomers were perplexed at the alarming import of their own deductions. A hundred years have scarcely elapsed since the astronomer Halley startled the world by announcing the existence of a flaw in the construction of the solar system, by which the certain though distant ruin of our earth was involved. He was led to this supposed discovery by a comparison of the eclipses of his own time with those recorded by Ptolemy in the second, and by Albutegnius in the ninth century. From this comparison it appeared to be established that the mean velocity of the earth in her orbit was increasing.

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The philosophers of that day were puzzled, nor was the cause of this circumstance explained until Laplace demonstrated that it was due to a diminution in the eccentricity of the earth's orbit round the sun, produced by certain perturbing influences in the planets. This orbit, as our readers know, is elliptical, and, as it was proved that this ellipsis tended to change into a "round" or circle, at the rate of about 41 miles annually, it followed that a perfectly circular orbit would be established in the course of 37,527 years.

But the conclusion to which this discovery led was frightful. The sure effect would be to draw the earth nearer and nearer to the sun, until at length the centripetal would so overbalance the centrifugal force, that our globe would fall helplessly into it. It is true, the lease of existence thus given to the earth, even on the most unfavourable estimate, was a long one; but its direful ending appalled contemplation, and concentrated upon the question the whole intellectual strength of astronomers. Never was the surpassing construction of the solar system made more strikingly manifest than when Laplace demonstrated that this "weak point" had not been overlooked by the Great Architect. In a way which cannot be here explained, but which has received the assent of all succeeding astronomers, he showed that the

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alteration in its orbit which the earth is now undergoing can only continue up to a certain point, and that, when this point is reached, other planetary influences will come into play, which, by gradually undoing the work that has been done, will ultimately bring back the earth once more into her old ellipsoid orbit. And when the limit is again reached in the latter direction, the "influences" will again change, and a new progress towards circularity will recommence. Thus, so far from leading to the destruction of our earth, this regular oscillation specially provides for its unlimited endurance; nor can anything stop the perfect machinery of our solar system, except the word of the Almighty Artificer who created it.

He hath made the round world so sure that it cannot be moved.—Ps. xciii.

In gazing at our fellow-planets, as on a clear night they stand out with preeminent brightness among the twinkling stars, who has not longed to penetrate the mystery of their being, and to know whether they, like our own earth, are worlds full of life and movement? The vast distance that intervenes between us forbids us to expect a direct solution of the question, for no instruments we can make, or even hope to make, will bring their possible inhabitants within the range of vision.

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We are reduced, therefore, to survey them with the sifting force of intellect, and to rest contented with such circumstantial proof as is derived from a knowledge of their general structure, and the analogies subsisting between them and our earth.

Among our nearest neighbours, Venus is nearly the size of our Earth; and Mercury and Mars, though considerably smaller, would still form worlds which, to our ideas, would not in their magnitude be so very different from our own. All the planets revolve in elliptical orbits round the sun, and the time consumed in this journey constitutes their year. Their polar axis is not "straight up and down," but leans over or is "inclined" to the plane of their orbit, so that each pole is turned towards the sun at one period of the year, and away from it at another. This arrangement insures the regular alternation of seasons and a variety of climates on their surface. The orbital inclination of Mars, for example, is much the same as that of the Earth, and therefore the relative proportion of his seasons must have a close resemblance to our own. It might be expected under these circumstances that ice would accumulate towards the poles in winter time, as on the Earth, and accordingly glacial accumulations have not only been observed by astronomers, but it has been remarked that they occasionally diminish by melt-

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ing during the heats of summer, while they increase in winter.

Again, the planets, like the Earth, turn round on their axis with perfect regularity, and those just mentioned do so in very similar periods of time. Hence all have their days and nights. These divisions represent in our minds intervals mercifully set apart by Providence for the welfare of living creatures—times designedly arranged to regulate alternate labour and rest in beings whose requirements in this respect would seem to be analogous to our own. Diurnal rotation, moreover, insures to each planet a determinate amount of light and heat from the sun, which is necessary to the well-being both of animals and plants; and it is measured out to them with a regularity equal to that with which we ourselves receive it. One can see no other purpose that could be served by diurnal rotation except the distribution of light and heat; and, if the axis of the planets had been "inclined" very differently to what is actually the case, this purpose would not have been so efficiently accomplished. The amount of light and heat received by the more distant planets must be necessarily small in comparison with our own supply; thus at Neptune it is a thousand times less than at our Earth. Still it is easy to conceive that by a corresponding increase in the sensibility of the retina nearly every

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purpose of vision may be adequately fulfilled. Even on our own Earth there are animals which see with an amount of light which to us is little else than darkness.

The next point of analogy is that most of the planets, if not all, are surrounded with atmospheres which distribute and refract the light, while they retain and intensify the heat, just as on our Earth. In some of them, indeed, as in Venus, the soft twilight is as visible to astronomers, as our own twilight is to ourselves. Earth has its atmosphere often charged with clouds, Jupiter is belted round with them; from which may be inferred the existence of an atmosphere and of water. An atmosphere must necessarily give rise to currents of wind. From the vast size of Jupiter, and the velocity with which his surface moves round at the equator, there must likewise be trade-winds of much greater force than our own. One effect of those stormy trades would be to give a streaky character to the clouds encircling tropical districts—a theory with which the appearance of Jupiter's famous belts exactly corresponds. The main divisions of the surface into land and water can be distinguished and mapped out in Mars, while chains of mountains are to be descried in Mercury and Venus.

Analogy carries the argument still further.

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Planets, like our Earth, have their moons, whose number and size are in some degree proportionate to the distance of the planet from the sun, or, in other words, to the urgency with which supplemental "lamps" are needed. Mercury and Venus, lying near the sun, bask in his light, and have no proper satellites, although they must act as moons to each other. Our Earth has one. Mars, though lying more remote from the sun than we are, has none. Jupiter, five times more distant from the sun than our earth, has four satellites disposed with such careful design that some of them are always shining. Farther off, in the darker regions of the solar system, Saturn's night is broken by the light of eight satellites, some of which are always full, as well as by his wonderful luminous "ring"; while Uranus has not fewer than four moons, and probably may have more over which distance has hitherto cast obscurity. As regards Neptune, his enormous distance must continue to make the number of his satellites a question of extreme difficulty. One, however, has already been discovered, and improved telescopes will probably reveal more. As corroborative evidence I need do no more in this place than merely allude to the recent results of spectrum analysis, or the chymical examination of the light itself which they transmit; from which it appears that not only the sun and planets, but

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even the stars, actually contain substances with which we are familiar here on earth.

That those planetary globes, with their continents and oceans so analogous to our own in the plan of their physical conditions and so vastly surpassing them in extent of surface, should be void and barren and destitute of life in every form, seems scarcely consistent with our knowledge of the ways of the Creator. All over our globe, except, perhaps, among the polar snows or in the desert, we see life abounding. Space is everywhere economized by Nature, and thriftily allotted out to living creatures. To promote the spread of life the most dissimilar spots have inhabitants expressly constructed for them, so that every place may become a home in which something living may exist. The abundance of Nature—the profusion of life is proverbial, and forces itself on our notice in every direction. Is it likely that those vast orbs—with masses and densities so wonderfully modified and adjusted in accordance with what we perceive to be the requirements of living creatures—with years and months, days and nights, seasons and climates—with atmospheres and twilights, trade-winds and currents—with clouds and rains, continents and seas, mountains and polar snows—with sun, moon and stars, and, in short, with all the elements that make up the conditions

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of a habitable globe—is it likely that those glorious works of the Creator should have been formed to lie waste, sterile, and unprofitable? Or even if we could bring ourselves to think that those masses, whose united bulk dwarfs our Earth to insignificance, had been created solely as make-weights to keep this little atom of Earth in its place, why should they have been provided with a complicated system of moons revolving round them to give them auxiliary light? The sun's light they share in common with ourselves, but for what conceivable purpose should deserts void of life have been supplied with those wonderful lamps to light them up in the absence of the sun? Our own moon, we know, was made "to rule the night," to give light to something that could profit by it; has the same beautiful machinery been repeated, and even more extensively than here, for the sake of globes where nothing living exists to which it can be of use? Not less wonderful, and for a purpose not less obvious, is the way in which the size and density of the different planets have been modified to harmonise with the probable strength and power of objects existing upon them. The very conditions that would be incompatible with our organisation may, from the adjustments of creative wisdom, be exactly suited to the beings called on to inhabit them. All life, even if it be essentially the same

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in principle, may not everywhere assume the same phase of outward existence, nor need we attempt to set limits in this respect to the Lord of Life. The spaces lie there furnished and ready—the Word only was required to people them with a life which may be different, but which, so far as we can understand the conditions, need not be very different, from life such as we see existing around us. Reflection upon these and other points seems to reverse the question with which we set out, and to make the difficulty consist in believing, not that life in some shape exists upon our fellow planets, but that they can be destitute of it. Such enquiries have an interest which goes beyond their mere astronomical import, for they touch our conceptions of God's Greatness. Is there any one who does not long to be able reasonably to cherish the thought that, far away from this tiny speck of Earth, in the remote realms of space we behold worlds inhabited by beings who, it may be, are privileged like ourselves to know their Creator, and to bless, praise, and magnify Him for ever?

We turn towards our nearest neighbour in the solar system with a sentiment bordering on familiar affection. We speak of it emphatically as "our moon." The sun we share with other planets, but this beauteous orb belongs exclusively to ourselves. Although we transmit to each other but little

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warmth, we yet cheer up the darkness of each other's nights by liberally reflecting the rays which each receives from the sun. Like loyal friends we give and we take to our mutual advantage; and, as the Earth is the larger reflecting body of the two, we repay with interest the light we borrow. To young and old the moon is ever interesting and beautiful. The infant questions it with delighted eye, and stretches out its tiny arms to play with or to catch it. From moon-land have descended some of the mysterious legends of childhood. The boy soon learns to recognise "the man in the moon," and the familiar face roots itself in his imagination for life. Its gentle light is associated with many pleasures. We welcome its first curved streak in the west as a sign that our gloomy nights are past; we watch it to "the full" with ever-increasing admiration, and we part from it at last with regret and hope. Our very dogs salute it with their bark; a notice they bestow on no other celestial object. Floating in the clear sky, or poised among the fleecy, tinted clouds, silvering the water or piercing through the trees—in every phase and aspect it is beautiful. Like an enchanter it casts the charm of picturesqueness over the meanest objects, and masses which look hard or ugly in the garish light of the sun mellow into beauty when touched by the power of the moonbeam.

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The moon's journey round our earth—the lunar month—is accomplished in a little more than twenty-nine days and a half. When interposed between the earth and sun she is invisible, because her dark side is turned towards us; but during nearly all the rest of her circuit she reflects a portion of the light received from the sun, and cheers our nights with brightness. The actual amount of light thus transmitted is small when compared with that which floods in upon us from the sun, being scarcely equivalent to the 300,000th part; and it has been calculated that were the whole heavens covered with full moons, it would not equal the light of the sun. The distance from the centre of the earth to the centre of the moon is 238,793 miles. An express train would easily clear the distance between the two globes in 300 days.

Unlike the active Earth, which rotates on its axis every twenty-four hours, the moon turns herself round only once in twenty-seven days seven hours and forty-four minutes. Everybody must have observed that the well-known features of "the man in the moon" never change; in other words, the same hemisphere of our satellite is always presented towards us. That this peculiarity is the result of the coincidence in point of time which exists between her axial rotation—constituting her day—and her orbital rotation round the Earth,

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for nowhere else can nature match this aspect of desolation. Fancy rather than science has tried to deal with such a scene. Some have conjectured that it might be an Earth burnt up and destroyed by the outpouring of God's wrath. Others have supposed that it is a comparatively recent world—a globe in a state of chaos—whose crust has not yet been sufficiently worn down by the hand of time to fit it for the abode of living creatures. Destitute of life it certainly appears to be at present, nor do its physical conditions seem to fit it for ever becoming the abode of that kind of life which we see existing on our own globe. Amid these conjectures let us fall back with thankfulness upon what is certain. Cosmically considered it performs its part in upholding the balance of our solar system; and, in reference to ourselves, we know that it was created by Our Father "to rule the night" and in other ways to shed blessings on His children.

Many of the mountains in the moon have been measured by ingenious mathematical processes, and at least one has been found to attain a height of 26,691 feet, which, though not quite equal to that of our highest Himalayan or Andean peaks, is yet proportionately higher, since the moon's diameter is little more than a fourth of that of the earth. As the rays of the sun fall obliquely upon them they are seen in profile—being bright on the side next the sun,

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and in dark shadow on the side turned away from it. Their peaked and jagged outline is best displayed along the inner margin of the crescent moon. Mountains in the moon present in miniature an exact counterpart of the effects which sunlight produces on the mountains of the earth. In alpine districts the rays are first caught by the loftiest peaks, then the side next the sun is brightened, while the side turned away from it still remains in shade. Lastly the western slope becomes illuminated, and the eastern in its turn passes into darkness. In the moon the mountains may be observed to undergo changes in their lighting up which are precisely of the same nature.

From the absence of those effects that would necessarily result from the refraction of light, astronomers conclude either that the moon has no atmosphere, or that, if it exist, it must be as attenuated as the air in the vacuum of an air-pump. For the same and for other reasons it is also to be inferred that water is equally wanting. During the long moon-day of half a month, the sun's rays beat fiercely upon its surface, and would certainly send up clouds of vapour if any water existed for them to act upon. The result would be to cover the moon with a nebulous screen impenetrable to vision,—a condition which is plainly inconsistent with the fact that whenever the earth's atmo-

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sphere is clear, we always see the moon with the same unvarying brightness. According to Dr. Lardner, however, there might possibly be ice, for "in the absence of an atmosphere, the temperature must necessarily be not only far below the point of congelation of water, but even that of most other fluids," and he points to the fact that, even under the burning sun of the tropics, the rarefied condition of the atmosphere existing at a height of 16,000 feet upon the Andes produces a cold which converts all vapour into snow and ice. On the other hand, it seems clear that, if ice existed in the moon, some amount of vapour could hardly fail to be produced by the long-continued action of the sun, and we know that in the tropics clouds hang round even the highest peaks. If there were a cloud even 200 yards in extent, it would be visible to us by telescope. Thus all arguments tend to prove that the moon is destitute of water.

The Earth and our satellite, as has been said, mutually interchange their good offices, and shine upon each other as moons. A curious illustration of this is seen when the dim outline of the rest of the moon fills up the hollow of the bright crescent, or when, in popular phrase, "the young moon has the old one in her arms." We all know it is the reflected rays of the sun which makes the crescent visible, but how is it that we are able to

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see the rest of the moon upon which the sun is not shining? It is by what is termed "earth-shine," or by means of those rays which in our quality of moon we send across to her. The "earth-shine" on the moon is pale and shadowy, but we must recollect that the rays which bring it to us have travelled many a weary mile. They sprang originally from the fountain of the sun, and had to speed across some 92 millions of miles before they reached our shores. They were then the young and joyous rays that dazzled our eyes by their brightness. The Earth next caught them up, and cast them, softened into mild moonlight, across the 238,000 miles of space that separates us from our satellite. And lastly, these enfeebled remnants of light, after having brightened up Luna's rugged surface, were sent back once more across the wide gulf to the Earth, bringing with them to our eyes the dim image of the moon they had left behind.

Some may be inclined to ask,—How happens it that this earth-shine is not seen at other phases of the moon? It arises from the circumstance that the crescent moon always coincides with the period when our fully illumined disk is turned towards it. We are then at the "full." Our lamp-power, therefore, is at its highest, and is strong enough to produce the earth-shine. But when the moon is about half full, not only is our lamp-power diminished from our "phase" in relation to the moon having

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been changed, but the more extensive illumination of the moon herself by the direct rays of the sun obscures and, as it were, "puts out" the more feeble earth-shine that was previously visible.

From the comparative nearness of the moon, and the perfection gradually imparted to optical instruments, many have been bold enough to anticipate that we shall some day see in it the familiar objects of every day life, or even the Lunarians themselves, if any do exist. This rather unreasonable expectation has been from time to time encouraged by premature announcements. Thus, on one occasion, it was given out that a town had been plainly distinguished in the moon; on another, that a fortification with roads and canals were equally discernible. But these supposed discoveries have never received subsequent confirmation. On the contrary, Mädler, of Berlin, has pointed out that it is in the highest degree improbable we shall ever be able to observe objects so small as the human figure. The extreme distance, he remarks, at which a man is visible to the unassisted eye is a German league. Now, to bring an object in the moon to that apparent distance would require a magnifying power of 51,000, while with all our modern skill in instrument-making, we do not as yet possess any power which magnifies more than 6,000 times.

Scripture as well as experience and common sense tells us that the moon was made "to rule the

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night," but some have objected to the obvious meaning of the expression, if not to the perfection of the work itself, on the ground that the "lamp" is only occasionally lighted up. The observations of Laplace certainly sanctioned the opinion that the moon might possibly have been placed in the heavens in such a position as to be always "full" to us; but this advantage could only have been purchased at the cost of the loss of light that would have arisen from increased distance. As things are actually regulated, more or less moonlight brightens our earth on most nights of the year, and few months pass over without our practically experiencing the advantage of the light which has been placed by Our Father in the heavens for our use. In arctic regions the moon and the stars alone break through the darkness of the long winter's night, and all who have read the story of polar voyages will recollect the thankfulness with which moonlight is welcomed and appreciated. The Arab of the desert steers on emergency by the light and position of the moon. Over the pathless seas the moon is the navigator's friend and counsellor. It places in his hand a certain scale for measuring the longitude and fixing the spot where the ship may be. When we think of the fleets of noble vessels, the wealth of merchandise, and the thousands of lives whose safety is dependent on

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its teachings, we may form some estimate of the value of this blessing. "Without the moon's aid," an astronomer observes, "our ships, instead of fearlessly traversing the ocean from pole to pole, would probably even now be incapable of performing long voyages, and would content themselves with exchanging commodities and intelligence between well-known and neighbouring shores."

Of old the moon played a more important part than she now does in the notation of time; but, among many Eastern peoples, the moon still indicates the seasons, while its different phases serve as an almanack to mark particular days. Among the Jews the new moon was associated with certain religious ceremonies, and men were stationed on the hill-tops to give the earliest notice of its approach. Some Orientals are also accustomed to indicate the seasonal stages of vegetable life by the epithets they apply to the moon;—thus there is the rice-moon, the wild-strawberry moon, the leaf-falling moon, and there is likewise an ice-moon. We have, at least, our glorious Harvest-moon. Nor is the moon unrecognized in our Church festivals; for Easter is always celebrated on the Sunday following the first full moon which happens on or after the 21st March, or vernal equinox.

The Heavens declare the glory of God; and the firmament sheweth His handiwork.—Ps. xix.

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THE STARS OF HEAVEN.

O ye stars of Heaven, bless ye the Lord: praise Him, and magnify Him for ever.

HE who turns his thoughts star-wards will speedily find his power of distinct conception strained to its utmost effort; for as the distances, magnitudes and movements with which we are familiar upon earth are dwarfed by those of the Solar system, so do the latter in their turn shrink into insignificance when compared to the distances, magnitudes and movements of the Stellar Universe. Miles now become useless, and no longer speak to us with their old intelligible meaning; and the other familar aids that helped us on in the comprehension of Solar measurements are scarcely more serviceable. The locomotive with its 30 miles an hour, the cannon-ball with its flight of 500 miles an hour, are all too slow to mete out distances such as are now to occupy us. Nothing but light itself,

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cleaving through space with a velocity of 192,000 miles a second—or, according to Foucault's latest estimate, 186,000 miles a second—can supply us with a standard capable of representing the remoteness of the more distant, visible stars.

In the immensity of the plans and natures revealed by astronomy we miss those homely illustrations of providential design which are so often impressed upon us in our daily experience among the familiar objects around us. But, on the other hand, we behold in their mightiest development the laws governing that Universe of worlds which peoples the realms of space, and among which our spot of earth occupies so humble a position. In presence of this grand view the physical details of our little globe seem almost too petty to be remembered. The Omnipotence and Infinity of God confront us with all the vividness which our finite understanding can conceive, and we bow our heads in heart-felt adoration.

By the Word of the Lord were the Heavens made, and all the hosts of them by the breath of His mouth.—Ps. xxxiii.

The "Hosts of Heaven" are truly called innumerable, and, as we glance upwards on a clear, starry night, the twinkling points that meet our gaze in all directions seem to defy enumeration. Yet, strange though it may appear, the sum of all

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the stars that can be distinguished by the naked eye in both hemispheres under the most favourable circumstances does not exceed 6000, and of these considerably less than a half belongs to our own northern division. But, when the telescope is turned towards the sky, stars come forth in myriads from the dark depths of the firmament; and, as each additional light-grasping power is given to the instrument, a new region of the heavens is joined on to those that have been already explored; and every new stratum of space thus added is found to be studded with stars in an ever increasing ratio. It is difficult to estimate the number which may thus be brought into view, but astronomers compute it to be not less than 100 millions. To a superficial observer the stars seem scattered about as if by chance, but a more careful inspection reveals that some fixed law of distribution, which we cannot as yet unravel, reigns supreme among them. "Suppose," says Dr Nichol, "a number of peas thrown at random on a chess-board, what would you expect? Certainly that they should be found occupying irregular or random positions; and if, contrary to this, in far more than average numbers, arranged by *twos* upon each square, it would be a most natural inference that here there is no random *scattering*." Appearances, indeed, have convinced some most eminent astronomers that our own solar

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system—in its entirety—has been planted in the midst of a cluster of stars, of which the exterior rim is composed by the encircling stellar hoop of the Milky Way. Lying beyond the Milky Way are other clusters, which may represent similar systems, but which, at all events, display a certain, recognisable, general structure; and the same may be said of the still more remote nebulæ, whenever it has been possible by the aid of the telescope to resolve them with any degree of fair distinctness into their proper forms. In picturing the distant regions of space Dr Nichol observes: "Mystery, indeed, heavy, almost oppressive, hangs over all the perspective; but the shapes strewn through that bewildering territory have nothing in common with the fantastic creations of a dream. It is the essence of these nebulæ that they are not formless, but, on the contrary, impressed indelibly by system on the grandest scale; clearly as a leaf they have an organism; something has seized on their enormous volumes, and moulded them into a wonderful order." Thus every thing bears the mark of order impressed upon it by the Almighty hand. That noble gift of God to man—the telescope—has magnified Him by driving away every semblance of chance from the firmament, and by exhibiting in its place design and established law. Up there as down here the idea of irregularity or chance is but the suggestion

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of our own ignorance. How far into space our view has been carried by the power of the telescope we shall immediately endeavour to point out.

Certain groups of stars, named Binary and Multiple, are interesting to us in many respects, and in none more so than from their exhibiting the harmony and order amid which they exist. The telescope reveals to us that two or more stars are sometimes linked together in the relation of sun and planet, or rather as co-ordinate suns revolving round each other, or round a common centre. These Binary stars display the evidence of design and power as convincingly as is done by the members of the solar system. The same law of gravity with which we are so familiar on earth, is proved to be in full operation among them, and their orbital revolutions in obedience to it have, in some instances, been observed and calculated upon the same principles as those by which the movements of the planets are determined. With more perfect instruments and a sufficient allowance of time for the collection of data, their movements may, at some future day, be chronicled with as much accuracy as the other sidereal events of the almanack. Yet so well are the orbital movements of some stars understood, even now, that a "perturbation" or deviation from the usual path has been detected in the bright Sirius, of the same nature as

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happened in the famous case of Uranus; and calculations indicating the position in which the "perturbator" would be found were made on the same principle as those which led to the discovery of the planet Neptune. Nay more—the disturbing mass which caused the star to stagger in its path has been seen through an American telescope, in the very quarter to which the finger of science had already pointed, and the discovery has since then been amply confirmed. We shall immediately have to consider the distance of the field in which this scrutiny was held. "When a branch of science," says Guillemin, "scarcely known two centuries ago, and cultivated steadily for less than a hundred years, arrives at such results, what may we not hope for in the future progress of sidereal astronomy."

Binary and multiple stars—being suns—are probably attended by their planetary systems, giving rise to cosmical conditions of extreme interest. The inhabitants of those earths—if there be any—will frequently see two suns, or two sunrises and sunsets on the same day. Occasionally there will be no night, from the continuance of one of the suns above the horizon; or one sun may be rising while another is setting. It often happens too that the stars are of different colours, from which the most singular and beautiful appearances will arise. "It may be easier suggested in words," says Sir John

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Herschel, "than conceived in imagination what a variety of illumination two stars, a red and a green, or a yellow and blue one, must afford a planet circulating round either, and what charming contrasts and grateful vicissitudes—a red and a green day, for instance, alternating with a white one and with darkness—must arise from the presence or absence of one or other or both, from the horizon."

The most striking wonders of the Firmament are comprised in the distances, magnitudes and velocities of the stars, and it may well excite both our astonishment and our gratitude that we, the humble dwellers upon an atom of earth, should be privileged to gauge them with even approximative accuracy. Yet the principle on which astronomers have succeeded in measuring the distance of a few of the nearest stars is none other than that by which the surveyor maps out an estate or a county. It is an ordinary problem of triangulation. There is no doubt as to the truth of the principle employed, and there is no mystery in the process: the difficulty lies in the inevitable imperfection of the instruments with which the necessary measurements must be made. But every new improvement in the measuring power of instruments cancels a certain amount of previous error; and even now there is among astronomers—working separately and independently—so wonderful an agreement in regard

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to the vast distances involved, that it is impossible to suppose either that such coincidence is accidental, or that there can be any very material amount of error in the estimates thus formed.

Has my reader ever heard of the parallax of the stars? The most unlearned need not be dismayed at the scientific look of the expression, for the principle involved in it is in reality most easy to understand. It will, indeed, largely repay a few minutes of attention, for it is the ladder by which we shall best climb to a clear conception of those truths of the stellar universe which illustrate so grandly the Power of the Creator. And even where the conclusions to which it leads baffle the efforts of our finite faculties, the definite basis on which they rest will at least banish every idea of guesswork from our thoughts.

It is easy to understand that parallax movement is that *apparent* shifting of bodies which arises from changing our own position. We cannot stir a step without producing examples of it. If we pace up and down the street opposite to any object on the other side—as a door or a lamp-post—the angular direction or parallax of the object changes at every moment. If we sail down a river and fix our eyes on some church spire at a distance from its bank, we find that the direction in which we see it is always altering. At first the spire appears in ad-

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vance of us, then on our side, and lastly it lies behind. If instead of limiting our attention to one object we look at several that can be easily observed together, we find that as we move they move, or rather seem to move, and the angles formed by their lines of direction are displaced relatively to each other and to us. One cannot look out of a railway carriage without being amused by the way in which objects seem to move about. Trees, houses, and churches are never for a moment at rest. Things that are in line "open out," as sailors would say, near objects are moving backwards, the more distant are moving forwards. In this apparent change of position we have an example of parallax movement. In all these cases the line from which our observations are made is the "base;" and if the angle subtended by the objects from the extremities of this base be given, the distance may be easily calculated.

In all instances of this parallax shifting it must have been remarked that the effect of a change of our position in altering the direction of objects is greater when they are near than when they are distant. A few paces will sensibly alter the angular position or direction of the door or lamp-post on the opposite side of the street. But if we look at a church some miles off, or at ships anchored in the offing, we find that we require to move much more

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than a few paces—in other words, we require to increase considerably the length of the base—before we can make any sensible change in the angle or direction in which we see them. In proportion, therefore, as the distance of objects increases, so must we lengthen out the base from which we survey them in order to obtain parallax displacement. It follows, too, that if in observations taken from a short base line objects appear to have changed much, we may infer that they are near; but, if the base require to be long in order to produce an effect, we may equally infer that they are distant.

Such is the plain and certain principle which astronomers applied to measure the distance of the stars; but the great difficulty was to find a base line long enough to give parallax displacement to objects so remote. Stations in this country were obviously too near for such a purpose. Simultaneous observations were therefore made from Greenwich and the Cape of Good Hope—the distance between the two stations of course representing the "base"—and from these the most interesting and important results were obtained. For it was found that, though a distinct parallax movement could be traced in the planets, none whatever could be detected in the stars. And it followed, therefore, that while the planets were comparatively near, the distance of the stars was such that a still longer

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base was needed to bring them within the grasp of parallax.

The line from Greenwich to the Cape having failed, astronomers next had recourse to the base represented by the diameter of the earth's orbit. As our globe revolves annually round the sun, it is obvious that it must occupy a very different position in space at one period of the year from what it does at another. On the 1st January it is at one extremity of its ellipse, on the 1st July it is at the point exactly opposite, and the length of a line drawn from the one station to the other is 190,600,000 miles. Could it be doubted that a base line was at last obtained long enough to ensure a parallax for any conceivable distance?

It may well be imagined with what astonishment the fact broke upon astronomers that, even from this enormous base, the keenest scrutiny could not detect the slightest displacement among the stars! Not one apparently changed its position. The result perplexed philosophers, for it forced the conclusion upon them either that the Copernican doctrine of the earth's orbital movement round the sun was an error altogether, or else—what seemed almost as difficult to believe—that the base line yielded by the earth's orbital diameter was but an inappreciable point in relation to the inconceivable distance of the stars. For

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generations, therefore, "to discover the parallax of the stars" was one of the grand astronomical problems; but while the chief observers strove earnestly for the prize, the best among them failed to carry it away. The triumph was reserved for our own time.

In truth, however, this want of success in demonstrating the parallax of the stars was no reproach to the older astronomers, for it depended on causes over which they had no control. To accomplish this grand object instruments of great delicacy were essential; and instruments have only been brought to the requisite degree of perfection within the last few years. But, be it remarked, what those old philosophers could not register with the hand they yet saw clearly with the head; and, therefore, with perfect faith in the truth of the Copernican theory of the world's movement in space and in the ultimate solvability of the problem, they never lost heart, nor ceased to strive for its accomplishment. At length in 1839 the long looked-for discovery was made almost simultaneously by two observers of equal merit;—our countryman, Henderson, at the Cape, having succeeded in measuring the parallax of a star known as α Centauri, while Bessel had already been equally fortunate in regard to 61 Cygni. It is pleasing to think that these astronomical triumphs, after being

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scrutinized and tested in almost every great Observatory possessed of instruments sufficiently fine for the purpose, have stood their ground and been substantially confirmed.

The difficulty of the feat becomes at once obvious when we consider the small sum of the stellar displacement obtained, which even in the case where it was greatest, did not quite amount to one second of a degree. But the conclusion that was to be drawn even from so inconsiderable a parallax was astounding; for, when the necessary allowances had been made, it was proved that the distance of the nearest of those stars from the earth was nearly 20 billions of miles. How can we get into our minds some idea of so great a distance? The standard of miles seems utterly vague and profitless. Do we succeed better when we are assured that it is equal to 206 thousand times the space separating our planet from the sun; or 211,330 radii of the Earth's orbit; or that a ray of light darted from its surface could not reach our eye under three years and seven months, though it travelled with its usual speed of 192,600 miles a second? "Such then," says Sir John Herschel, "is the length of the sounding line with which we first touch bottom in the attempt to fathom the great abyss of the sidereal Heavens."

"First touch bottom!" Let us pause, and take

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breath. Let us try soberly to realise the fact that this flight, through which our imagination has carried us on the wings of a ray of light, has landed us only at the threshold of the starry universe. So far as is yet known this famous star of the Centaur is our nearest neighbour. Of the thousands of others whose parallax astronomers have tried to measure, there are not more than a dozen where it has been detected, and all of them lie at various distances beyond. The well-known Sirius—the very star whose perturbations, as we have seen, have already been calculated and accounted for by visible demonstration—which from being the brightest among stars was conjectured to be also the nearest, has been proved by parallax measurement to be at least six times the distance of α Centauri; from which it follows, that every ray of that dazzling orb that now meets our eye set out on its journey towards us some twenty-two years ago. One of the most distant stars that has as yet been gauged is the beauteous Capella. In expressing its enormous distance we may discard all other standards of measurement save that which light supplies; and even a ray of light, with its speed of 192,000 miles each second, would take 72 years to reach our earth. As for stars placed at greater distances the base line of the earth's orbit, seconded by the most perfect modern instruments of measurement, fails

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as yet to demonstrate with reliable accuracy any sensible amount of parallax. In relation to those distant orbs, a base line of 190,600,000 miles shrinks into a mere point.

The belt of measurable parallax, therefore, proves to be but a comparatively shallow layer of the firmament. All "the Hosts of the stars" lie farther off in regions which no parallax can reach. A longer base line than 200 millions of miles would be needed to continue the survey, and unfortunately the resources of astronomy do not as yet supply any that are available. We say "as yet," for it is not impossible that a longer base may at some distant future day be found if, as is almost certain, our sun itself is moving in an immense orbit round *something* in space, and carrying along with it the whole solar system. The diameter of the sun's orbit may then afford a base line of immensity sufficient to conquer the difficulties of distant stellar parallax. Of the interval which would necessarily elapse between the observations made on such a base no one can now imagine the duration.

At that depth in the firmament, therefore, where Capella lies—representing a space to pass through which light would require 72 years—we come to the limit of parallax. With it ends the means which enable star-measurements to be placed on a reliable

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basis, and all beyond is subject to the greatest uncertainty. Are, then, our estimates of the distances of stars sunk farther away in space than Capella to be absolute guess-work? By no means, thought the illustrious Sir W. Herschel, for when parallax can plumb no longer, light still affords a line which measures immensity with at least a rough approximation. It is true that this method sets out with the hardy assumption that the size and illumination of the different stars are the same; whereas we know with certainity that both are subject, like the planets, to much variation. Nevertheless it may, perhaps, be assumed with considerable probability, that in the multitude of stars examined there must at least be some to which such a method will apply, and which therefore may serve, in the absence of all other means, as a rough measure of the depths of space beyond Capella to which the eye of man can penetrate. All are familiar with the fact that light diminishes as we recede from it, in proportion as the square of the distance increases. If, for example, one luminous body be twice as far removed as another equally luminous body, it will give four times less light; if it be ten times as far off, it will give a hundred times less light, and so on in proportion. Now it has just been shewn that the distance of α Centauri, an average star of the 1st magnitude, is in

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round numbers 20 billions of miles, while it shines with an amount of brightness which, by means of an instrument called a photometer, can be measured, and adopted as a standard from which to set out. A star of the 6th magnitude, just visible to the naked eye, is found to have a light 100 times less bright than α Centauri; and, therefore, it must be ten times more distant, supposing the luminous surface to be the same in both. We have now got a second standard of measurement, according to which it may be assumed that a star having a brightness which we can just discern is 200 billions of miles distant. Here we are, for a moment, necessarily brought to a stop, for our unaided sight is unable to force its way farther into space; and here, therefore, our survey must have come to an end but for that wonderful "tube," by means of which the regions lying beyond have been fathomed to an extent that almost overwhelms. It fortunately happens that astronomers can "scale" a telescope, according to what is termed its "space-penetrating" power. When, therefore, it is said to have a space-penetrating power of 50, it means that we can see with it 50 times farther than with the naked eye—50 times as far, therefore, as the distance lying between us and the star of the 6th magnitude which has just been measured. Sir W. Herschel, whose name will ever be remembered

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in connexion with this subject, penetrated into space 75 times farther than the distance which separates us from a star of the 6th magnitude, by which he brought stars thus deeply sunk in space to shine with a brightness equal to stars of that class. Now, what was the stupenduous import thereby implied? A star of the 6th magnitude is at least 10 times more distant than α Centauri, its distance, therefore, is 200 billions of miles; and the star 75 times more distant than the star of the 6th magnitude must have a distance of not less than 15,000 billions of miles! How is this distance to be expressed by an intelligible standard? It is equal to 170 million times the distance of the sun from the earth—the unit being 92 millions of miles. Told off by terrestrial standards these figures sound vaguely and seem to stupefy the ear, nor indeed can any other measure than light rise to the level of such distances. It is astounding to think that the few straggling rays of light which at length found rest in Herschel's eye might have left their native sun 2656 years ago, although they had been travelling at the rate of 192 thousand miles a second ever since. The messenger arrives only now, but he speaks of an old event. "It is within the scope of physical possibility," says Dr Lardner, "that those stars may have changed their conditions of existence, and consequently of appearance, or

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even have ceased to exist altogether more than 2000 years ago, although we actually see them at this moment."

But even those distances, stupendous though they be, do not represent the full depth of that fathoming of space which has possibly been effected by modern instruments. What shall we say of the Nebulæ—those "wisps" of cloudy light that faintly gleam down upon us through the telescope from the remotest corners of the universe to which we can force our vision? As the more perfect instruments of recent days conquered their secret, one after another, and resolved the hazy cloudlets into clusters of bright stars, the conclusion naturally arose that, with every new increase of penetrating power, we should only behold a repetition of the process. There do, however, appear to be some Nebulæ which cannot be so resolved, and which show no indications of condensing into stars; and "spectrum analysis"—that potent discovery of yesterday, which is able to extract from a ray of light its history by passing it through a prism—comes to the support of the telescope by declaring that such distant glimmers are due to vast volumes of luminous gaseous matter. But, making allowance for these, there still remain many Nebulæ of true stars—suns like the rest, heat-giving, and light-giving, and animated as our little Earth is by the same universal

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principle of gravitation. A certain cluster of stars was estimated by Sir W. Herschel to be 700 times the distance of a star of the 1st magnitude—therefore, at least 700 times 19 billions of miles! But, observes Guillemin, "if this cluster were removed to five times its actual distance, that is to say to 3500 times the distance of Sirius, the large Herschelian telescope of 40-feet focus would still show it, *but only as an irresolvable Nebula.* It is, then, extremely probable that, among the many Nebulæ indecomposable into stars, beyond the Milky Way, in the depths of the heavens, many are as distant as that of which we speak. *Doubtless many are more so.* Now to reach us, light-rays must have left stars situated at such a distance more than 700,000 years ago!"

On such a subject I prefer to transcribe words recently written by an astronomer, and they at least claim our attention as the latest conjectural opinions of science. That such calculations are but the roughest of wide approximations—that they are liable to error of a magnitude which in any other branch of physics except universe-measurement would make them utterly valueless, is a point admitted by none more readily than by astronomers themselves. Still, after every deduction for probable error has been made, more than enough of solid truth remains to leave our highest conceptions hope-

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lessly stranded behind, and it would even mock our power of belief did not reason tell us that such conclusions are in perfect accordance with the attributes of Omnipotence. When we have touched the verge of this uttermost range, Infinity, boundless as ever, still lies beyond. The idea of God extinguishes in our mind every suspicion that there can be any limit to space, magnitude, or power, in relation to His works. The mighty universe we have been considering is but the stepping-stone to what is farther on; and although our imagination fails to grasp it, our reason assures us that it must be so. There is no such thing as taking from or adding to The Illimitable.

The distance of the stars is likewise impressively brought home to us by the impossibility of magnifying them. It is easy to magnify terrestrial objects, and even when the telescope is pointed at the planets, as Venus or Jupiter, they can be made to look bigger than the full moon. But with regard to the stars the telescope fails to increase their size, for they are absolutely "unmagnifiable." Viewed by the highest powers they still remain mere specks of light; and, although their comparative brightness is increased, no one star is really made larger than another. When, therefore, the "magnitude" of a star is mentioned it refers to its brightness, and not to the size of its nucleus.

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As the telescope cuts off the external rays, its effect, indeed, is rather to diminish than enlarge, and Herschel used to affirm that the more he magnified the more the nucleus appeared to shrink to a point. But as the faithful telescope, by virtue of its construction, cannot help magnifying the image of the star presented to it, and yet fails to give it any appreciable size, we are driven to infer that even the nearest stars are so remote that their apparent magnitude is too minute to be perceived by the eye, though magnified, as was done by Sir W. Herschel, six thousand times.

This result appears all the more astonishing when we consider the vast magnitude which the stars must really possess. As they do not form any distinguishable disk, it is of course impossible to calculate their size from their known distance and apparent diameter, as may be done in the case of the moon; but astronomers possess other means by which their magnitude may be at least roughly estimated. It has been already mentioned that, as we recede from a luminous surface, the quantity of light received from it diminishes as the square of the distance increases. By applying this principle, the sun furnishes us with a means of measuring the magnitude of stars, always assuming, as may be done when the trial is extended over a great number, that the average intensity of the luminous

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surface is nearly the same in both. We know that the sun, being of a known size and at a known distance, gives a certain amount of light as determined by the photometer. Supposing that the sun were to be moved away from us in the direction of α Centauri, his light would diminish in the proportion in which the square of the distance increased; and, accordingly, before he had got much more than half way, he would have dwindled to the size of α Centauri. If the sun were to be farther removed, his brightness would go on diminishing until at the distance of α Centauri—19 billions of miles—he would shine as a star of the 2nd magnitude, or like the Pole-star. Thus it appears, that in order to enable the sun to shine with a light equal to that of α Centauri at the same distance as that star, he would require to be twice his actual size; and, therefore, the magnitude of α Centauri may be roughly estimated as double that of our sun.

In contemplating "the stars of Heaven" by the aids which astronomy holds out to us, our thoughts are carried away from the small things of this earth, and, borne onwards by the faculties bestowed on us by God, we reach our highest practical perceptions of His Power as Creator and Ruler of the Universe. We cannot, it is true, comprehend The Infinite, but astronomy sta-

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tions us nearer to its frontier than any other science, and we are only stopped in our conceptions by that barrier which subdues all human intellect, and beyond which it is not intended that we should pass.

Not less marvellous are the stars in their velocities. We speak of them as the "fixed" stars, and so they are to us for all practical purposes; yet some, if not all, have a movement through space. Binary stars, as we have seen, circulate in orbits round each other, or round a common centre, with a regularity and speed which in some instances has been calculated. The star 61 Cygni—the same whose parallax has been measured—rushes through space with the enormous velocity of 177,000 miles an hour; while Mercury, the swiftest of our planets, does not exceed 100,000 miles in the same time. A star in the constellation of Ophiuchus, and another in the Scorpion, are moving on so rapidly as to leave neighbouring stars behind them. There is a triple star in Cassiopeia journeying through the heavens at the rate of 125,000 miles an hour. Arcturus is the most rapid star-traveller yet discovered, moving onwards at a pace equal to 54 miles per second, or three times faster than our earth in its orbit. Thus everything connected with the stars—distance, magnitude and motion—is equally gigantic and marvellous in its scale.

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Having glanced at the distances, magnitudes and velocities of stars, let us pause for a moment to consider their number and the vast space they must necessarily occupy in the domain of creation. In an area of the Milky Way not exceeding one-tenth part of the moon's disk Herschel computed that there were at least 20,000 stars, and by the most moderate estimate the number of stars that can be counted in the firmament by telescopic aid does not fall short of 100 millions! Clusters and Nebulæ that have not yet been resolved lie beyond. There is little doubt that most of those twinkling points are suns dispensing light and heat to earths or planets like our own; and, indeed, no bodies shining by reflected light would be visible at such enormous distances. From the superior magnitude of those stars that have been measured, as compared to our sun, it may be assumed that the average diameter of their solar systems must exceed our own; but, taking it as nearly equal, it would give a breadth of at least 6000 millions of miles as the field in space occupied by each. Every star or sun-system is, moreover, probably begirt with a gulf or void like that encircling our own, in which the antagonistic or disturbing attractions of surrounding suns waste themselves out and are extinguished; hence, the distance of each star from its nearest neighbour is probably not less than that which inter-

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venes between our sun and the nearest star. Now this distance, as we have seen, cannot be less than 19 billions of miles. How inconceivably vast, therefore, must be the space required to give room for so many and such stupendous solar systems. The mind absolutely reels under the load of conceptions so mighty. Yet Infinity still lies beyond!

Among those great Hosts of heaven where is the home of our Earth and Solar system? A probability lying nearer to certainty than conjecture suggests that our sun, with its planetary system, forms a unit in a cluster of stars, similar to other clusters which we see gathered together in the far-off regions of the firmament. The space occupied by our cluster may in shape be compared to a millstone, of which the Milky Way forms the outer rim; while nearly in the centre of this gigantic assemblage of stars, and about half way between the two sides of "the millstone" rests our sun and its planets—"an atom in the luminous sand" of the firmament.

Still, we must not say *rests*, for there is absolutely nothing on earth or in the firmament which is without movement. That our sun—like all his fellow-stars—is travelling through space with a speed which though not yet determined is certainly immense, is a point on which astronomers are agreed. The most recent calculations assign to it

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a rate of four miles per second. Whither are we hurrying, round what are we moving? These are problems of which the solution is left to future observers, yet even now calculations tend to indicate that we are hastening on with rapid strides in the direction of the constellation Hercules. Who has not looked on clear nights at the twinkling Pleiades, and tried, perhaps, to count their sparkles as they glitter like diamonds on a field of black. Their name recalls to us a heathen fable, but they have an interest far more lasting and reasonable if it be true, as astronomers conjecture, that among them is fixed the pivot which is central to the centre, and round which our sun with its system careers in an orbit whose length it is as impossible for us to conceive as the distance of the stars themselves.

If astronomy were altogether silent on the subject, it would still be a hard matter for a reflecting mind to believe that the masses which fill up space, the aggregate sum of which dwarfs our earth into less than an atom or a speck, can have been created for no other purpose than to shed a glimmer of star-light on our dark evenings. "For what purpose," says Sir John Herschel, "are we to suppose such magnificent bodies scattered through the abyss of space? Surely not to illumine our nights, which an additional moon of the thousandth part of the size of our own would do much better—not

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to sparkle as a pageant void of meaning and reality, and to bewilder us among vain conjectures. Useful, it is true, they are to man, as points of exact and permanent reference; but he must have studied astronomy to little purpose, who can suppose man to be the only object of his Creator's care, or who does not see, in the vast and wonderful apparatus around us, provision for other races of animated beings."

Though placed at such inconceivable distances from our earth, stars are yet near enough to contribute to the happiness and safety of mankind. During the sun's absence they bestow an illumination which, though feeble, is highly useful. When the moon has forsaken the long polar night they cast a dim twilight over the snow. In the deserts of the East, stars have served to guide the traveller since those ancient days when astronomy began to be cultivated on the plains of Chaldea. The pilots of antiquity learnt to steer by the stars before the loadstone was discovered; and, in these days of science, sun, moon, and stars may be said to cover the firmament with lamps and sign-posts. Familiarity with the fact has long dulled within us the feeling of surprise, still it is a wonderful thing to think that, in the most lonely spots of the trackless ocean, the position of a ship can be told with accuracy by questioning the aspects of the heavenly

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bodies. By means of sun, moon, and stars, aided by a chronometer keeping Greenwich time, or by the Nautical Almanack, both latitude and longitude may be certainly determined. To these aids every ship that sails upon the wide ocean is daily indebted for safety, nor could anything bring home to us more strikingly how even the most remote works of Our Father are made by his providence to subserve the welfare of His children.

With what just propriety of thought has light been called the "voice" of the stars. Through light alone comes all the knowledge we possess concerning them. Had light been created with less marvellous properties than those it actually possesses, even their existence would have been unknown to us. Can anything be conceived more suggestively true than the expressions with which the Heavens are described by the Psalmist?

> There is neither speech nor language, but their voices are heard among them.
>
> Their sound is gone out into all lands, and their words unto the ends of the earth!

In the "speechless" voice of light the stars proclaim to us from the depths of space the existence of innumerable other worlds which, like our own, share the Creator's care. Silently they tell us of distances, magnitudes and velocities which transcend our power to conceive. With mute argument stars prove

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to us that, in those far off regions, gravitation—the power that brings the apple to the ground—still reigns supreme, and with suggestive whispers of probability they persuade us that, like our own bountiful sun, they bathe attendant worlds in floods of brightest light, deck them in colours of beauty, and shower countless blessings on the life of myriads of beings.

He who by thoughtful contemplation has familiarized his mind with the wonders of the Heavens will feel his whole spirit imbued with the glory of the Great Architect, by whose Almighty Word they were called into existence. To him sun, moon, and stars, silent though they be, will speak a language which he will ever deeply feel even though he may not always comprehend. Nor will they fail, when solemnly invoked in the Service of the Church, to stir up responsive adoration in his heart, for they symbolize to him more than any other visible objects the Wisdom and Power of the Creator.

Whoso is wise will ponder these things, and they shall understand the loving-kindness of the Lord.—Ps. xcvii.

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WINTER AND SUMMER.

O ye Winter and Summer, bless ye the Lord: praise Him, and magnify Him for ever.

THE great Architect has appointed that the earth, like its fellow planets, should make an annual journey round the sun in a path which is not far from circular. During this time the earth is separated from the central luminary of our system by a mean distance of 92 millions of miles, which has been designedly fixed as securing to it the reception of that exact amount of heat and light which is best suited to the requirements of all the beings found upon it. Any other distance than this would, in fact, have been incompatible with the order of life we see established around us. But, besides this general arrangement as to distance, there are certain modifications in

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connection with it which affect most remarkably the local distribution of heat over the globe, giving rise to seasonal variations—to Winter and Summer, and to differences of climate. In looking at an astronomical diagram it will be remarked that the sun is placed, not in the centre, but in one of the foci of the ellipse which the earth's orbit describes round it; and the result of this necessarily is that the earth is nearer to the sun at one period of the year than it is at another. The conclusion is naturally suggested that this period of "nearness" must coincide with summer, and that of distance with winter; but, strange though it may appear, it is exactly the reverse. On the 1st January the earth is about one-thirtieth part nearer the sun than it is on the 21st June.

It is clear, therefore, that the cold of winter and the heat of summer must depend on other causes acting with power sufficient to overbalance the effect which this relative nearness or distance of the sun ought naturally to produce. Such a cause is found in the inclination of the earth's axis to the plane of its orbit. The effect of this arrangement can be easily illustrated by an impromptu orrery. Let a card placed near the centre of a round table represent the sun; a ball of worsted will be the earth, and a knitting-needle thrust through its centre will form its axis and poles. The

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rim of the table conveniently traces the earth's orbit round the sun, while the flat surface forms the imaginary "plane," on a level with which the centre of the sun and earth are supposed to be arranged. The earth's axis, it must be recollected, is not perpendicular to this plane—not straight up and down—but is inclined towards, or leans upon, it at an angle of 23½ degrees. If we now apply the centre of the worsted ball, or earth, against the rim of the table at the point farthest removed from the sun, giving the knitting-needle, or axis, an inclination towards the sun to the amount specified; and if we then slide it round the rim, taking care not to alter the direction of the inclination, and to make the needle always maintain the same parallel throughout, we have a rough imitation of the orbit which the earth describes in its annual journey round the sun.

But let us draw attention more particularly to the point of this arrangement on which the alternation of summer and winter depends. If, on starting from that part of the rim of the table which is farthest from the "sun," the upper or north "pole" of the worsted ball be inclined towards that luminary, it will be found that on arriving at the side of the table exactly opposite—and nearest to the sun—the same "north pole" is now inclined away from it. Exactly the reverse of this has, of course happened to the "south pole;" it inclined at

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first from, but now inclines towards the sun. The necessary effect of these changes of position is to place that side of the earth, which for the time being leans toward the sun, in a more favourable position for receiving light and heat than the side which is inclined away from it. The result thus produced upon the temperature much more than compensates for the heat either gained or lost on account of the comparative nearness or distance of the earth in relation to the sun at the two periods of the year, and it therefore rules the seasons. In the hemisphere which is inclined toward the sun there is summer; while, in that which is inclined away from it, there is winter. Everybody knows that when it is summer in England it is winter at the Antipodes.

When we consider the forethought with which the conditions of animal and vegetable life have been adjusted to the distance of the earth from the sun—to their respective sizes and densities—to the length of the earth's orbit—to the velocity with which it travels, and to the nicely poised inclination of its axis—we cannot fail to be deeply impressed with the admirable design of the Creator and the excellence of His Power. All these elements had to be adjusted, one with the other, in order to establish Winter and Summer, and the least deviation in any of them from the condition which actually exists would

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have spoilt the harmonious working of the whole. The beauty and necessity of these arrangements have been happily illustrated by Dr. Whewell: "The length of the year or interval of recurrence of the seasons is determined by the time which the earth employs in performing its revolution round the sun: and we can very easily conceive the solar system so adjusted that the year should be longer or shorter than it actually is. We can imagine the earth to revolve round the sun at a distance greater or less than that which it at present has, all the forces of the system remaining unaltered. If the earth were removed towards the centre by about one eighth of its distance, the year would be diminished by about a month, and in the same manner it would be increased by a month on increasing the distance by one-eighth. We can suppose the earth at a distance of eighty-four or one hundred and eight millions of miles, just as easily as at its present distance of ninety-six millions: we can suppose the earth with its present stock of animals and vegetables placed where Mars or where Venus is, and revolving in an orbit like one of theirs: on the former supposition our year would become twenty-three, on the latter seven of our present months. Or we can conceive the present distances of the parts of the system to continue what they are, and the size, or the density of the central mass, the sun,

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to be increased or diminished in any proportion; and in this way the time of the earth's revolution might have been increased or diminished in any degree; a greater velocity, and consequently a diminished period, being requisite in order to balance an augmented central attraction.—In any of these ways the length of the earth's natural year might have been different from what it now is: in the last way without any necessary alteration, so far as we can see, of temperature. Now, if any change of this kind were to take place, the working of the botanical world would be thrown into utter disorder, the functions of plants would be entirely deranged, and the whole vegetable kingdom involved in instant decay and rapid extinction.—That this would be the case, may be collected from innumerable indications. Most of our fruit-trees, for example, require the year to be of its present length. If the Summer and the Autumn were much shorter, the fruit could not ripen; if these seasons were much longer, the tree would put forth a fresh suit of blossoms to be cut down by the Winter. Or if the year were twice its present length, a second crop of fruit would probably not be matured, for want, among other things, of an intermediate season of rest and consolidation, such as the Winter is. Our forest-trees, in like manner, appear to need all the seasons of our present year

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for their perfection; the Spring, Summer, and Autumn, for the development of their leaves and consequent formation of their proper juice, and of wood from this; and the Winter for the hardening and solidifying the substance thus formed."

As a general rule it may be said that temperature falls in proportion to increase of latitude; at first slowly, and then more rapidly. Our daily experience of midday sun and sunset teaches us that oblique rays give much less heat than those that are more nearly vertical; and as the earth is round, and as rays from the sun, therefore, fall on it all the more obliquely the greater the distance is from the Equator, it follows that in high latitudes, where the globe from its shape curves in rapidly towards the poles, the temperature will fall with accelerated ratio.

Such is the cosmical arrangement by which the general supply of heat is meted out to the earth, but there are many circumstances which modify this distribution, so as to produce great differences of climate in places that are on nearly the same latitude. Thus, in proceeding northward from the tropics, the mean annual temperature falls much more quickly in America than in Europe. For example, the cities of Madrid and Philadelphia are both situated at nearly 40 degrees of latitude; but the mean annual climate of the former is 9° higher

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than that of the American city. In comparing places farther to the north the difference is still more striking.

We have space in this chapter to notice only very briefly some of the causes which modify climate. The reader will find many additional observations bearing on this subject in those sections of this book wherein Mountains, Winds, Ice and Snow, the Sea, and the Green things upon the Earth are considered.

The great equaliser and mitigator of extremes of heat and cold is the ocean. A maritime climate is for the most part moderate in its seasonal changes, in comparison to an inland climate on the same latitude. In Winter, the sea being warmer than the land tempers the winds which blow towards it; while, in Summer, as its temperature is lower than the heated surface of the shore, it imparts fresh coolness to the breezes. Warm or cold ocean currents, if they be extensive, have much influence on climate. Thus the great Gulf Stream, laden with the heat of the Tropics, by laving the shores of Western Europe, and more especially those of our own islands, sensibly moderates the rigour of the Winter; while, on the other hand, the cold current from the Greenland Sea and Baffin's Bay, which streams past Newfoundland and the Atlantic shore of North America,

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materially lowers the climatic temperature of those countries.

As a general rule, the effect of a deep inland or continental position in temperate regions is to give what is called an "extreme" character to the climate,—that is, to make it colder in Winter and hotter in Summer than other places on the same parallel of latitude which are surrounded by or near the sea. To illustrate this point the climate of Warsaw in nearly 52° 13′ may be contrasted with that of Dublin in 53° 21′. Warsaw lies on the great plain of Central Europe. In Winter, the surface over a wide tract around loses its temperature under the influence of the long nights and keen frosts, while there is no neighbouring sea to mitigate the cold. Had the ocean been near, as its temperature does not fall under 40° Fahrenheit, it would have corrected this rigour; but, instead of the comparatively warm sea, there is an extensive land surface, which, being cooled down far below the freezing point, imparts to the air passing over Warsaw much of its own intense rigour. Dublin, on the other hand, by having a maritime position, enjoys during the Winter a far milder climate, although it lies more than a degree farther north. The temperature of its coldest month does not fall below a mean of 37°, while that of Warsaw sinks to 27 degrees. In Summer, however, the same physical conditions

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produce exactly the contrary effect. The sandy plains round Warsaw get baked in the sun, and the air in passing over them is heated as in an oven; but round Dublin there are no scorched plains, and the sea that encircles Ireland tends still further to cool the temperature. Hence, while the mean of the hottest month at Warsaw is 70°, that of Dublin is only 60°. Thus Warsaw is 10 degrees colder than Dublin in Winter, and 10 degrees hotter in Summer.

To similar causes is to be attributed the extreme character of the climate throughout the greater part of North America. At New York, for example, the thermometer in summer often rises to above 100° in the shade; while during the winter of 1866 it fell to 15° below zero, and marked 28° in places more inland. The explanation of this excessive rigour is that most of this vast continent lies far from the sea, while it stretches in unbroken continuation into the frozen regions. In the same way Central Asia chiefly owes its "extreme" climate to its distance from the ocean.

Although there be no Winter or Summer within the tropics and in certain adjacent districts in the sense in which we understand them, there is nevertheless a division of the year into "wet and dry" periods, which, in their influence on the functions of animal and more especially of

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vegetable life, have effects analogous to those produced by the warm and cold seasons of higher latitudes. In the wet season vegetation is most vigorous; but, after the dry season has continued for some time, the grass withers and dries up, the deciduous leaves fall, the growth of plants is arrested, and the vegetable world reposes very much as in the winter of more northern climes. The analogy between these seasons is still more strikingly shown by the torpor into which some animals fall during the dry season, just as elsewhere they pass into a state of hybernation during the winter. Thus when that reptile-looking fish, the Lepidosiren of the river Gambia, perceives that the waters are falling on the approach of the dry season, and that food is becoming scarce, it buries itself in the mud, and there awaits in a dormant state the return of the rains. Sir J. E. Tennent has noticed other animals in Ceylon which become torpid during the dry season in the mud of the great water-tanks, and more extended observation will probably add to the list.

Nowhere, from the force of contrast, is Summer more brilliantly joyous or its approach welcomed with greater delight, than in polar regions, where amid perennial frost and snow Winter seems to be enthroned for ever. The long, continuous night, after passing through a tedious dawn, at length

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opens into that bright, brief interval in which spring, summer, and autumn are blended into one. In rays of warmth the sun sends forth the signal, and nature promptly answers to the call. As heat increases, the solitude once more shows signs of life and movement. The frozen lumps and ledges covering the sea begin to strain and crack and split asunder, and glacier masses breaking loose from their icy cables yield themselves up to the current and the wind. Food is no longer absolutely wanting, and many creatures that have been slumbering through the winter now shake off their torpor. Torpor enforced, but merciful! As winter approached, supplies of food ran short and then became exhausted, so God in kindness sent them sleep. Hunger was extinguished in lethargy. It was needful to husband the forces of vitality until the time of abundance should again come round; so the heart was made to beat, and the lungs to breathe, at the lowest rate that was compatible with existence. The expenditure of fuel to maintain animal warmth was thus brought down to its minimum, and the lamp of life was sparingly fed with the fat which nature had providentially stored up in the body when food was plenty. But now, called forth by light and warmth, the bear creeps from its lair of snow, and seals and walruses begin to gambol round the rocks where lately solid ice sealed up

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the surface of the deep. Myriads of migratory waterfowl from the warm south whiten the inshore cliffs. Then the Esquimaux, rousing himself from the enforced idleness of the long night, sallies forth to hunt and fish, and to gather up supplies of food in snow-built safes against the never-distant Winter. The short, thick grass and moss spread their carpet of green over every sheltered spot from which the snow has melted, and the rest of the scanty but often brightsome flora of remotest North puts on with marvellous rapidity its summer aspects.

Diversity of climate and season—of Winter and Summer—over the globe has produced for man's advantage a corresponding variety of animal and vegetable life. Man himself has an organic strength which enables him to exist in every clime; but other animals, and all plants, have a more limited geographical distribution, and are endowed with constitutions which fit them for thriving in certain regions only. By means of commerce however, the shortcomings of one climate are supplemented by the riches of another, and all the most useful productions growing upon the earth are thus most widely scattered. This necessary interchange, moreover, becomes a means of knitting the whole world in bonds of mutual dependence.

We may rest assured that nothing in nature has been established without benevolent design,

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and even the difficulties arising from the proverbial uncertainties of climate, as well as the impediments encountered in the cultivation of the soil, are not without their use. Everything shows that we are here as in a training school, and surrounded by circumstances which, by demanding the energetic exercise of our faculties, tend to preserve and strengthen them. In man's contests with the so-called faults of climate, he is, for the most part, reasonably victorious. His prudent foresight, his ingenious contrivances, his dexterous wielding of science to avert evils and improve opportunities, are continually showing how abundantly the Creator has supplied him with all means needful for his welfare, in whatever quarter of the world his lot may happen to be cast.

Diversity of climate circumscribes within limits more or less narrow many of the most useful of our food-producing plants, but this unavoidable evil has sometimes been lessened or obviated in a way which affords another instance of the kind forethought of Our Father. One of the most useful articles of vegetable diet is sugar, and nature has taken care that many substances in common use shall contain a fair proportion of it. At the same time, there are certain plants in which it exists so abundantly that we are accustomed to resort to them for our large supplies. Of these the chief is

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the well-known "cane." But the sugar-cane flourishes only in the tropics and adjacent regions; and therefore all sugar from this source consumed in extra-tropical countries must be brought to them by commerce. Many a wide district, however, lying far in the interior of continents, is unfavourably situated for thus receiving its supplies, and it might either have been deprived of that article altogether, or at least have been inadequately provided with it, had not Providence, with kind intent, created other sugar-producing plants constitutionally suited to different climates, for the purpose of distributing the gift more generally over the world. Thus we find that, from the "cane" region to the Mediterranean, the supply of sugar is maintained by several plants, among which may be mentioned the date-palm and the fig. Beyond this, in climates corresponding to southern Europe, there are the sorghum and maize, from which much sugar is now manufactured in France and America. Farther to the north the beetroot in the field and the maple in the forest extend the system of sugar-producing plants almost to the confines of the arctic circle. In another article of diet, which from its importance we are accustomed to call the "staff of life," a similar providential succession is observed. Farinaceous food is tropically represented by the rice-plant in

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great abundance; in proceeding northwards rice is associated with the maize or Indian corn; that is succeeded by wheat; and lastly, we have oats and barley flourishing almost up to the North Cape. The same representative system is observed in regard to many other important vegetable principles with more or less distinctness. In this manner, then, the difficulties opposed by climate to the wide distribution over the globe of some of the most valuable products of the vegetable kingdom have been entirely surmounted. It is clear that, according to the laws which regulate the vegetable kingdom, it was impossible for the same useful plants to flourish everywhere; but Providence has created duplicates, as it were, to yield abundantly the same products, and has adapted them by their constitution to take up their position in the different climatic belts of the world, in order that no extensive region should be without them.

With all their imputed faults of climate, we have no occasion in these favoured islands to envy the plantal glories of warmer regions. In absolute beauty who shall say that we are not on an equality, whilst the great charm arising from the well-marked progression of the seasons is more especially our own. Nothing is more frequently debated than the comparative attractions of the

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different periods of the year, and certainly no season—not even excepting Winter—need be without its admirers. The never-ending contrasts which every season spreads before us unquestionably contribute much to enhance our enjoyment. Never do "green things" seem so green or flowers so bright as when our first glimpses of them are caught through the opening portals of the Spring. Then do we feel more than at any other time the great value of this seasonal alternation. How gladly the eye wanders over and reposes upon the "universal garb" of nature. To the beauties of Summer and Autumn we are led up as it were through an avenue which, by gradually preparing us for what is to follow, lessens in some degree the keenness of our relish. The banquet is more varied, but the freshness of the appetite is wanting.

Though Winter may yield in beauty to other seasons, it is yet universally felt to have special attractions of its own. There is much to admire in the cheery, ruddy glow of the sun, in the noble and picturesque though naked forms of the woods, in the hoar-frost on the grass, in the sparkle of the ice-gemmed trees, the stalactites of crystal, and the wreaths of snow. Even in Winter's gloomiest moods the comforting thought is ever rising to our mind, that the stillness we see around is not death but needful repose spread over nature in mercy, and

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that the woods will soon again be clothed in green, and vocal with the songs of birds.

Winter has yet another aspect by which it is endeared to us. At Christmas-time it is crowned by the great Festival of the Church and of the family. Then, while nature slumbers in wood and field, Winter is brightly and lovingly awake around the hearth, gladdening millions of hearts with warm affection. Families that were scattered by the various calls of life once more gather together to enjoy the present, glance at the past, and treasure up new associations for the future. Then shops put on their gayest looks, and young and old press eagerly forward in search of the little gifts that are to make others happy. Streets and railway stations are thronged with bustling groups hurrying on to claim from expectant friends the cordial welcome of the season. Here and there, too, may be seen the "knotless threads" and waifs of the world drawn onwards by the social influence of the season towards some genial home, where, for a time, the sense of loneliness will be forgotten. At Christmas the Church and the Home seem to draw closer to each other, and the thoughts awakened by the solemn festival mingle with and temper the current of family rejoicing. Christmas is pre-eminently the season of "good-will towards men." Under its kindly impulses the mind softens with sympathy,

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and, while keenly alive to the blessings that fall to its own lot, is more heedful, perhaps, than at other times of the plaints of the less fortunate. The parish workhouse is for the day made radiant with merry faces, and Charity enters through its gloomy gates to spread the feast in honour of the Anniversary. In the good soil which Christmas thus prepares in the heart old friendships revive and new affections quickly strike their roots; while animosities, curbed by the gentle influences of the season, shrink out of sight, or are swept away altogether in the gush of better feelings.

The lot is fallen unto me in a fair ground: yea, I have a goodly heritage. Ps. xvi.

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NIGHTS AND DAYS.

O ye Nights and Days, bless ye the Lord: praise Him, and magnify Him for ever.

WE have already alluded to the Earth's orbital movement round the sun, from which our year results; and we have now to direct attention to that other movement of the Earth by which, in turning upon its axis every 23 hours 56 minutes and 4 seconds, it gives rise to the division of time into nights and days. How perfect the working of that machine must be by which this division is meted out may be inferred from a calculation by Laplace, which demonstrated that "it was impossible that a difference of one hundredth of a second of time should have occurred between the length of the day in the earliest ages, and at the present time!"

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Reverting for a moment to our impromptu orrery, it is obvious that if the ball of worsted, representing the Earth, were to be held steady during its solar orbit, so as not to turn round on its axis, one hemisphere of its surface would be directed towards the sun for one half of its circuit, and the remaining hemisphere during the other half. In other words, a whole year would be divided into one long day and one long night. During the day the sun would always be above the horizon, and the accumulation of heat which would thus accrue would far transcend the hottest tropical climate. In the other hemisphere, turned away from the sun, there would be a constant loss of heat from radiation, and as no compensatory rays would be received from that luminary, the temperature would sink below that of the frozen regions. It is clear that such an arrangement would be incompatible with the conditions under which life now exists upon our globe. Having regard to the constitution that has been given to animals and plants, it is absolutely necessary that heat and light should be meted out to them at intervals sufficiently frequent to guard against extremes of temperature. Therefore it is ordained that the Earth shall revolve once upon its axis in a period nearly amounting to twenty-four hours,—an arrangement by which twelve hours of alternate day and

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night, of warm sunlight and cool darkness, are secured to each hemisphere. By the aid of certain cosmical conditions, elsewhere noticed, modifications in the distribution of light and heat are produced, by which animals and plants might obtain that particular length of day and night which is best suited to their nature and habits.

The intervals of night and day are, moreover, in perfect harmony with that law of nature by which all animals require seasons of rest to alternate with periods of activity. The demand for repose is universally felt and obeyed. Even plants may be said to have their days and nights, in the sense of intervals for activity and rest; but the hours for labour are struck by the seasons—by orbital and not by axial rotation. In spring, summer, and autumn the sap circulates briskly, the manufacture of wood proceeds without intermission, and the various special products, as gum, starch, sugar and other matters, are elaborated. But on the approach of winter—or towards the evening of their long day of work—plants turn weary, and, by a poetical yet truthful figure, we habitually speak of them as "falling asleep." So necessary is this period of repose that, in the tropics where there is no winter's cold to chill them into rest, nature wraps them in salutary torpor by means of the sun's fierce rays. And

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how gladdening the dawn after the long night when plants awake from their sleep, and burst forth once more to resume their day of work!

Night mercifully beckons the world to rest. The busy sounds of day cease to distract the ear, and nature gently points towards repose. How sad when the silent hours of darkness refuse to steep in sweet oblivion the senses of the care-worn, or to dull the racked nerves of him who languishes upon a bed of sickness. Sleep is best wooed by labour—it is the reward with which nature blesses exertion. How grateful sleep is to the busy workers of the world; to the drones only is it apt to be, like their life, a listless, scarcely enjoyed vacuity. Night, too, calls us to meditation. When darkness drops its curtain over the things of earth, the mind is prompted to look inwards. The brief but salutary retrospect of the day should then be made, and the account closed. In prayer the soul finds peace, and sleep steals softly on amid thoughts that recall the Divine protection.

My trust is in the tender mercy of God for ever and ever. Ps. lii.

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LIGHT AND DARKNESS.

O ye Light and Darkness, bless ye the Lord: praise Him, and magnify Him for ever.

AMONG those Works of the Lord to which this Hymn appeals there is not one more full of blessings to mankind than Light, or one which more praises and magnifies the Creator. But, though many of the laws by which Light is governed are now well known, its essential nature is still a mystery. Some philosophers suppose it to be an "emanation" from luminous bodies of inconceivably minute atoms which act on the retina of the eye like odorous particles on the nerves of smell. Others refer its phenomena to "undulations" excited in a subtle ether pervading space, and travelling onwards to the eye by a movement resembling waves in the ocean.

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This theory, therefore, points to an analogy with the sense of hearing.

How wonderful is the construction of that little instrument by which light is made to minister to vision! There is truly nothing in the whole range of nature which more convincingly demonstrates design than the mutual adaptations of eye and light. This organ, equally perfect in contrivance and in finish, exhibits the most wonderful combination of organic power with a mechanical apparatus formed on the regular principles of optics. We see objects by reflected light; in other words, the object must first be illuminated, and then it must reflect a certain amount of this light into our eyes. But as the entrance of too many or too bright rays would have dazzled vision, while too few would have left it obscure and indistinct, an ever vigilant sentinel—the iris, on which the colour depends—was posted in front across the interior of the eye, to regulate, by the expansion or contraction of the pupil, the exact number of rays that ought to be admitted. It was also necessary that the rays, after entering the eye, should be made to converge so as to depict a distinct image on the retina, or nerve of vision, spread out at the back of the organ. For this purpose a lens, as clear as crystal, has been fixed up immediately behind the pupil, to "refract" or bend the rays into the proper focus.

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Not less careful has the Creator been in regard to the safety of so delicate an apparatus. To preserve the eye from injury, it has been sunk as deeply in the face as was consistent with the free range of vision; it is defended all round by strong ridges of bone, and made to move softly on an adipose cushion. Eyebrows, moreover, have been placed above, and fringing eyelashes in front, to guard against excessive light; while, by the rapid movement of the eyelids, the tears are diffused over the surface of the eye exposed to the air so as to keep it moist and glistening. Such are a few only of the beautiful contrivances exhibited by this organ.

Light, though colourless and invisible, is in reality made up of seven different tints, which again may be reduced to three—red, yellow, and blue—out of which the others are formed. The whole series is finely displayed in that separation of light into its constituent parts which takes place in a prism of glass or in the water drops of the rainbow. Objects which absorb nearly all the rays are black; those which reflect them all are white; and we owe the charm of colour to the circumstance that most bodies, while decomposing the rays of light that fall on them, absorb some of the constituent tints and reflect the others. By the endless combination of these last every variety of

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colour is produced. In many ways colours are convenient and useful, nor will any one deny that the face of nature would have lost its highest charm had not this property been bestowed on light.

The sun is the great fountain of Light; but, without the co-operation of the atmosphere to diffuse it over objects, the illumination of this earth would have been most imperfect, and light could never have become the universal blessing which it now is. Objects on which the direct rays of the sun fell would, of course, have reflected light and been visible; but objects which were in shade, and which, therefore, did not receive any direct solar rays, would have been invisible. Let any one attempt to realise the confusion into which the world would thus have been thrown. Even in the brightest sunshine we should have seen things only in broken fragments. The varied beauty of scenery would have vanished, and every landscape would have been disfigured with seams and patches of inky blackness. The rays of the sun in passing through a window would have brightened the surfaces they touched, but all around would have been left in almost midnight darkness. In conversing with a friend, the side which was turned towards the sun would alone have been visible; and, if our own face had happened to be opposite

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to his and in shade, he could not have seen it. If a cloud had passed over the sun both of us would have vanished into darkness, as if from a sudden eclipse. The azure tints of the firmament would have disappeared, and the stars would have shone at mid-day from a vault of utter blackness. To improve the illumination it was, therefore, essential that something should distribute the light, so as to supply objects that were in shade with a certain amount of rays, by the reflection of which they might be seen. This task was given by the Creator to the atmosphere. Many of the sun's rays fall directly on the earth, but the rest are caught up by the air, and are reflected and re-reflected from one particle to another, and are scattered and diffused in every direction, until all objects within their influence are bathed in light. In this manner bodies in shade are illumined and become visible by reflecting into our eyes more or less of the light they have received at second hand.

The service which the atmosphere renders to the sun, in diffusing its light equally over objects, is amply repaid by the sun in co-operating with plants to purify the atmosphere. A healthy condition of the latter is of primary necessity to our welfare; and, as the air is continually being vitiated in a variety of ways, some active agency is needed to check deterioration and

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preserve it in a state of purity. The essential constituent of the air is oxygen, which is diluted with nitrogen to a certain degree; and with this mixture is invariably associated a small proportion of carbonic acid gas. The latter is poisonous; but, under ordinary circumstances, the quantity existing in the air—only about one 2000th part of its volume—is too small to be attended with any inconvenience. There are, however, many causes in operation continually tending to destroy this balance, and to produce a noxious excess. In the first place, we manufacture the poison within ourselves to an extent which, though small in the individual, is enormous in the aggregate. With every inspiration we draw into the lungs a certain amount of oxygen, which, after combining with a certain amount of carbon or charcoal, is expired in the shape of carbonic acid gas. Now, although a small proportion of this acid was inspired as a constituent of the air, the quantity evolved exceeds by sixty times the quantity taken in; so that the whole amount of carbon thus daily carried off from the lungs of a healthy adult is not less than from nine to twelve ounces. When we multiply this unit by the population of the world, and add to it the product of respiration in the lower animals, we may imagine the extent to which the atmosphere is vitiated from this cause.

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A quantity of carbonic acid gas still more enormous is produced by combustion, the decomposition of animal and vegetable matter, and by fermentation. Every candle and every lamp sends forth its little rill of poison into the air, while from fireplaces and furnaces it issues in streams. In all these cases the chymical action is the same;—the carbon of the fuel is changed into carbonic acid by its union with oxygen gas.

Notwithstanding these sources of vitiation it is found experimentally that the relative proportions of the constituents of the atmosphere vary very little, and that the amount of carbonic acid diffused through it never exceeds its due quantity. It is obvious, therefore, that the Creator must have set some potent machinery in motion to correct and purify. Rain and surface water carry off more or less of the gas, and some mineral springs sparkle with it; but the work is chiefly done through the agency of Light upon the leaves of plants. When it is said that we "vitiate" the air in breathing, the expression refers only to its salubrity as regards ourselves and other animals; but we should greatly err if we supposed that this apparent spoiling subserved no good purpose. That which vitiates the air to us only prepares and perfects it for the use of plants; and the carbonic acid which would be poison to us is food to them.

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Thus the leaves, while bathed in air, extract from it the chief bulk of the carbon which is to build up the woody substance of the tree to which they belong. It is to be observed, however, that they can only perform this function so long as they are stimulated by Light. In darkness, plants, instead of purifying the air, tend to vitiate it still further by a slight evolution of the very gas which it is their special function to remove. But in the day-time, the leaf seizes upon the particles of carbonic acid gas that come in contact with it; and, while it "fixes" the carbon in its substance, it liberates into the air the oxygen which is to restore its purity. It might be thought that, as there are no leaves in winter to purify, the atmosphere would then become poisonous. But by the cosmical conditions of our globe it has been wisely ordained that it never is winter all over the world at the same time. The work, therefore, is always going on, though the scene of the laboratory is shifted. But besides this, the period of a single winter, with its dispersing winds and currents, would be too short to allow any injurious accumulation to take place. Thus to vast causes of vitiation are opposed vast agencies that purify, whereby the balance which works for the good of all organised nature is preserved.

At mid-day the unprotected eye cannot face the sun. But at sunset he ceases to dazzle, because

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his rays, from their greater obliquity, lose much of their fierceness while passing through the less clear and more vaporous layers of the atmosphere immediately investing the earth. The light is not only weakened, but it is altered in its character. In their passage towards our eyes many rays are absorbed and lost altogether, and many others are decomposed and only partially transmitted. Of the ray-fragments which thus survive and eventually reach our retina the red predominate; and hence the glowing hues of sunset.

When looking at the sun just as he begins to set, it is curious to reflect that he is not really where he appears to be, but actually below the horizon. We are, in fact, looking at his image or picture. There is a rim of the horizon interposed between us; he is in the position of the hull of a ship when, as sailors express it, the ship is "hull-down." Hence, were it possible that a cannon ball could be projected in a straight line right through the bright disk before us, it would not strike the sun, but would pass clean over it. This "lifting up" of the image of the sun is due to "refraction"—that property which has already been noticed as enabling the lens of the eye to bend the rays of light, and bring them to a focus on the retina. Refraction is familiar to every boy who has thrust a stick into clear water, and noticed the broken or bent appearance

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it presents at the point of immersion; and a spoon placed in a teacup into which a little water has been poured will exhibit it equally well. For our present purpose, however, this will be better illustrated by another very simple experiment. Let a shilling be laid at the bottom of a basin placed on the table, and let the observer then move slowly backwards, keeping his eye fixed on the piece of money, until the rim of the basin just intercepts his view. If water be now poured into the basin without displacing the coin, the latter will be as it were lifted up out of its real position, and will become visible. At first the shilling was seen in its true place. When the rays proceeding from it to the eye were intercepted by the rim of the basin, it became invisible. But when the water was added some of the rays from the coin in passing from the water into the air were "refracted," and bent downwards towards the eye so as to fall within the range of vision. Now as in refraction objects are not seen in the direction in which the rays originally left them, but in the direction in which the rays ultimately enter the eye, it follows that the coin is visible in its "lifted up" position. In applying this experiment to the phenomena of sunset, we may consider the shilling as the sun, and the intercepting rim of the basin as the horizon behind which the sun has really sunk. The media of water and air represent

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the dense, vaporous, impure lower strata of the atmosphere, which gradually "refract," or bend down towards our eye, the rays that come to us from the sun, and thus lift up its image above its real position.

To the "reflecting" power of the atmosphere we owe that interval of half-light which in the morning we call the dawn, and in the evening the twilight. Were it not for this property, we should pass at once from darkness to light and from light to darkness. When the sun sinks below the horizon, and when his direct rays have bid adieu to the dwellers on the plains, they still continue to tint the tops of the hills; and when, from the further dipping of the sun, these also have passed into shade, the slanting rays still enter freely into the higher regions of the atmosphere. Most of these rays continue their course into space and are lost to us entirely; but others are caught up by the particles of air and vapour, as by mirrors of inconceivable minuteness, and are turned back and reflected from layer to layer downwards until at length they reach the earth. The same operation is repeated as the sun approaches from the east in the morning. The soft, mild light of twilight is especially grateful in summer to eyes that seek repose after the hot glare of the sun. It is linked in most minds with pleasant associations. This is

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the time for leisure strolls on land or gliding movements on the water. It brings us into acquaintance with many animals which select it as their favourite period of activity. Soon as the swallows have ceased their twit-twit, the bats issuing from their retreat begin to occupy the vacant hunting ground, in which they display an activity on the wing scarcely less astonishing.

The length of twilight varies according to the latitude and the season of the year. It is shortest within the tropics, whose inhabitants may be said to plunge almost at once from light into darkness; and it lengthens as we proceed towards the poles. In the latitude of London, from the 22nd May to the 21st July, so much light lingers behind between sunset and sunrise that, speaking astronomically, there is no night at all. At the north pole night lasts from November 12th to January 29th; it is preceded by one long twilight continuing uninterruptedly from the autumnal equinox; and it is followed by a dawn reaching to the vernal equinox. During the whole of this period of six months the sun is below the horizon. Those who enjoy the blessing of alternate day and night every 24 hours, can hardly realise the intense thankfulness with which the dawn and the sun are welcomed by men who have just passed through the depressing influences of the dreary polar night. We

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can sympathise with Doctor Kane in his brig among the Greenland ice, as he records his eager watchings for the sun, and the calculations which, by revealing its daily progress towards him, permitted him to anticipate with certainty the day of its reappearance. We understand the thankfulness with which he must have watched the dawn growing brighter and brighter, and the delight with which at length he scrambled up a neighbouring height to catch a glimpse of the orb still hidden at the level of the deck. "I saw him once more, and from a projecting crag nestled in the sunshine. It was like bathing in perfumed water."

When wintering in the far north, Captain Sherard Osborn thus describes the return of the sun after an absence of 66 days. On February 7th "the stentorian lungs of the Resolute's boatswain hailed to say the sun was in sight from the mast-head; and in all the vessels the rigging was soon manned to get the first glimpse of the returning god of day. Slowly it rose; and loud and hearty cheers greeted the return of an orb which those without the frozen zone do not half appreciate because he is always with them. For a whole hour we feasted ourselves admiring the sphere of fire."

Light is one of the best and cheapest of nature's tonics, and, unless it be habitually absorbed, neither animal nor vegetable can permanently pros-

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per. Except in a comparatively narrow belt round the poles, this needful medicament is poured out at short intervals profusely over the world, and streams into every dwelling where it is not repelled by ignorance or folly. In man the habitual absence of sufficient light proclaims itself in the wan cheek and bloodless lip; and in plants, by the general want of green colouring matter. The blood that has been long shut off from the renovating influence of sunlight-air may circulate through the various organs, but it lacks the power to impart to them a healthy vigour. In the night time less carbon is expired from the lungs, and the purification of the blood, therefore, goes on less actively than during the day. The inhabitants of towns, where light is more or less excluded by lofty streets, are pale and feeble when compared with country cottagers, although their food may be both better and more abundant. Those who pass their days in dark alleys, or in the basement dens of crowded cities, seldom enjoy perfect health; and this is due not less, perhaps, to the want of light than to the want of air. Where light is defective elasticity forsakes both mind and body, and the spirits of few are so buoyant as to be altogether insensible to the difference between a bright and a dull day. In the weary polar night there is always a struggle against the depressing influence of darkness. When Kane,

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wintering in Smith's Sound, saw his crew drooping and dying round him, he probably did not err in attributing the calamity less to the want of good provisions than to the want of light. His dogs, too, perished one after the other with strange, anomalous symptoms which he attributed to the same cause, and he looked forward with confidence to the return of sunlight as the charm that was to stay the pestilence.

It would even appear that some plants, acted on by light, give off that mysterious kind of modified oxygen, termed ozone, which is believed to contribute so peculiarly to the healthy condition of the atmosphere. Nor is the pervading influence of light unfelt even in the inorganic world. To light we owe the beauties of Photography; and many other chymical actions can go on only under its stimulus.

"And God said, Let there be Light." Who can adequately appreciate the evidences of Power, Wisdom, and Beneficence crowded into this glorious creation, and how little do they comprehend its full value who see nothing in it beyond its convenience or its beauty! Light is an essential condition of animated nature—the pivot on which life turns. All that lives upon the earth lives by light. Without it plants could not grow, or assimilate their food, or breathe, or purify the air; and, without plants,

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animals must perish. From the mineral kingdom alone the food-supplies of the whole world are ultimately renewed, and plants are the appointed channels through which those supplies must pass. The vegetable organism rakes them together, gathers them up, and hands them over to animals in a state fit for food. "If," says Professor Draper, "we expose some clear spring water to the sunshine, though it may have been clear and transparent at first, it presently begins to assume a greenish tint, and after a while flocks of greenish matter collect on the sides of the vessel in which it is contained." This first addition to organised life is won by the power of Light out of the inorganic atoms round the germ; it is, as it were, the minute, base-material out of which the fabric of life is woven. "If the observation be made in a stream of water, the current of which runs slowly, it will be discovered that the green matter serves as food for thousands of aquatic insects which make their habitation in it." Next come fishes to snap up the insects, birds may seize upon the fishes, and both serve as food to man. In endless variety, and often through a much longer chain, some such general "succession of nutrition" is always going on. The whole movement was started by a beam of light!

Light is truly one of the great "Powers of the

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Lord." It summons the whole plantal world to labour in the purification of the air, and it regulates the hours of work. The wages it gives to plants for their willing service is their daily food of carbon. Hardly had the green matter in the stream begun to form under the influence of sunlight than it commenced the manufacture of pure air for the use of man, and in token of its activity it was gemmed all over with bells of vital oxygen. Land plants are no less busy in the same task, although their labour is necessarily invisible. Thus by the aid of Light no plant is idle, nor is it useless in nature's economy, though it may be unseen. Every scattered leaf and blade of grass has its appointed task, and every ray of light that falls upon them helps on the life of the world.

This is the Lord's doing, and it is marvellous in our eyes. Ps. cxviii.

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WATERS ABOVE THE FIRMAMENT.

O ye waters that be above the Firmament, bless ye the Lord; praise Him, and magnify Him for ever.

THE word Firmament is obviously used here in the same sense in which it is employed in the 1st Chapter of Genesis. It is that space which immediately invests the earth, and which interposes between the waters which are below and those which are above it, or between seas and clouds. The Scriptures abound with imagery derived from this source. Clouds shut out the bright sun—they were therefore emblems of gloom and sorrow; at other times they sheltered plant and beast from his scorching rays, and they were then the symbols of tender care and protection. Of old, too, as now, poets turned towards the clouds for some of their grandest metaphors. The Psalmist says, "The Lord maketh the clouds his

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chariot;" and when the inspired writer of the Revelation exclaims, "Behold he cometh with clouds," the expression symbolizes both grandeur and majesty.

Clouds are among the first of the objects invoked in the Hymn; and they are twice mentioned; once by themselves, as the "waters above the firmament," and again in another verse in connection with lightning. The prominence thus given to them accords with their importance in countries like Judæa and Mesopotamia, where droughts are sometimes severely felt. Clouds, therefore, were watched for eagerly and anxiously, as signs that the parched earth was about to be blessed with refreshing rain. Unhappy the regions where "the waters" never collect "above the firmament." There "the clouds drop no fatness," and the land loosens into sterile sand.

In our own country, and still more in hot climates, clouds often interpose as a friendly shield between sun and earth, to check excessive evaporation from the one, and to ward off the too scorching rays of the other. Without this protection the surface of the soil would dry up, roots would find no moisture, plants would languish or wither, and cattle might perish for want of water.

The vapour issuing from the spout of a tea-kettle supplies a favourite illustration of the theory

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of clouds, or they may be studied on a larger and very beautiful scale as they are developed from the funnel of a locomotive. With every puff of the engine a quantity of steam is driven into the air. It will be noticed that this steam is invisible at the moment of its escape, and when it has as yet scarcely cleared the funnel; then it is quickly condensed into a white cloud; and, lastly, this cloud itself disappears. A moment's attention to these three points will unfold to us much that is interesting in cloud-philosophy. It is well known that, when water is heated to a temperature of 212° Fahrenheit, it rapidly passes into invisible steam. The steam produced by the engine boiler was, therefore, as transparent as air on escaping into the funnel. But when steam is cooled below the temperature of 212° Fahrenheit it is condensed into vapour; hence the white cloud which the invisible steam of the locomotive formed on coming into contact with the colder air around it. Finally, we observed that as this cloud was diffused more widely through the air it dissolved and vanished.

This last fact proves that the atmosphere has the property of absorbing or dissolving moisture, which it retains in an invisible state. Air, indeed, always contains an admixture of moisture, though the quantity is continually varying. The warmer

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the air, the greater is its capacity to take up water in this invisible state; on the other hand, the colder the air, the less moisture it can hold. It follows that the atmosphere of the tropics is much more loaded with vapour than that of temperate regions; while this latter, in its turn, contains more moisture than the air of higher latitudes. We speak of "a dry air," but the expression is only relatively correct. There is always enough of water even in the dryest air to moisten saline substances that are deliquescent; and everybody has observed the streams condensed from unseen vapour which soon begin to trickle down the sides of a bottle of iced water brought into a room. Few people, however, would have expected to find that a cube of air measuring twenty yards each way and at a temperature of 68° Fahrenheit, is capable of taking up no less than 252 lbs. of water before it reaches the point of saturation. From this it may be imagined how enormous the quantity of water must be which is suspended invisibly in the entire atmosphere of the world.

It is out of this invisible steam pervading the atmosphere that visible vapours or clouds are manufactured. When one current of air meets another current colder than itself, they intermingle; and, if the resulting mixture be not of a temperature sufficiently high to retain in a state of invi-

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sibility the moisture that is diffused through both, the excess is necessarily condensed into cloud. The cloud itself is composed of particles or drops of water so extremely minute that they float in air. But if the condensation be pushed farther, the minute drops coalesce into larger drops, and rain falls to the earth. On the other hand, if warm or dry currents of air happen to set in through the cloud, it will be again more or less completely dissolved, as was observed in the case of the vapour puffed out of the engine-funnel. Hence the continual changes going on in clouds—their thinning, thickening, enlargement, diminution, and the other alterations of form.

The atmosphere owes its moisture to the evaporation going on at all temperatures both from land and water, and more especially from the great equatorial oceans of the globe. In temperate climates, like that of Europe, with a mean temperature of $52\frac{1}{4}^{\circ}$, the annual evaporation is equal to a layer of water 37 inches thick; but within the tropics it is much greater, varying from 80 to 100 inches. The great stimulator of evaporation is the sun, and clouds check evaporation by intercepting his rays. A calm is less favourable to it than a breeze; in the former, the air resting on the water soon gets saturated, and ceases to absorb; but a breeze sweeping over the sea is continually presenting to it new

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and thirsty portions of air, so that the process goes on with great activity. The water thus sucked up is carried off into the atmosphere as invisible vapour or steam, which is ultimately condensed into clouds. These may be considered as huge aerial tanks or reservoirs filled with water handed up by the ever busy air for the service of the earth. When clouds are not condensed in one place, the loaded air passes on with its burden to another; but sooner or later it is relieved either by the vanishing of the vapour through re-absorption, or by the formation of rain. Clouds may, in some degree, be regarded as regulators of atmospheric moisture, withdrawing it when in excess, and yielding it back when moisture is needed.

Besides supplying all the rain and filling all the rivers of the earth, the invisible moisture of the air is essential to the well-being both of animal and vegetable life. Were the thirsty air not abundantly fed with water from sea and land, it would in its eager search for drink suck out the moisture from every living thing, and in spite of all precautions we should soon pass into the condition of dried-up mummies. Our safety lies in the free admixture of water with the air, by which its keenness is tempered. Nevertheless it is astonishing to mark what care Nature has taken to protect the juices of plants and animals from this desiccating action,

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by investing them with coverings which are more or less impermeable.

In respiration the lungs cannot support an air which is too dry. When the supply of invisible vapour in a room is deficient, unpleasant sensations arise which are relieved by softening the air with steam from hot water. While wintering beyond Smith's Sound, Doctor Kane observed that his crew suffered from the excessive dryness of the air which, in breathing, was sensibly pungent and acrid. Nor is the invisible atmospheric vapour less necessary to the vegetable kingdom. Plants have the power of absorbing moisture not only by the roots but also through their leaves; and, in a fairly humid air, the evaporation going on from their surface is thus more or less checked or compensated. But in a too dry air this balance is upset, and the leaves droop or wither. The few plants that grow in the sandy desert are mainly dependent on the invisible moisture of the atmosphere for their supply of water, and the same may be said of those plants which live and grow when suspended in the air of a hot-house.

From the remarks just made it will be readily understood that clouds or wind coming from the north do not usually portend rain. The air, in passing southwards, has its temperature gradually elevated; and, consequently, its power to hold

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vapour in an invisible state is being constantly augmented. Hence, not only is there no rain, but the clouds themselves are often seized upon by the dry air and dissolved. But a south wind, on the contrary, comes loaded with the vapour which it sucked up when its temperature was comparatively high, and its capacity for carrying invisible moisture great. In travelling northwards it gradually cools, and the excess of moisture which it can no longer hold is condensed into clouds and rain.

Clouds are habitually less noticed than they deserve to be, and the pleasure which their contemplation is so well calculated to afford is too often lost from neglect. On fitting occasions cloud-gazing is no unworthy distraction wherewith to occupy a few of the fragments of time; and it belongs to those enjoyments which are all the more valuable because they so often lie within our reach. There is solid pleasure in letting our eyes lead fancy away among the mazes of cloud-land. What endless variety of form! The cirrhoid groups—how light, feathery, placid, gentle, and cheery! The bulky cumulus—stately, sombre, threatening! What is there grand in nature or in imagination which is not to be found among them? There are mountains and rocks, peaks and precipices, of which the aiguilles and domes of

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the Alps are but pigmy models, castles and cities, torrents and waterfalls! Imagination itself is beggared. Beautiful shapes float before our eyes for which we strive in vain to find a name. Under our gaze they melt, and change, and re-combine, as if to shew the limitless fancy of exuberant Nature. What colours!—the softest, the gravest, the richest, the brightest—hues of lead, copper, silver, and gold—all on a scale which mocks the rest of Nature's painting. What masses and magnitudes! Mounds of vapour, built up out of specky fragments, and rolled up the vault of the firmament by the power of the sun. In repose clouds are the emblem of majesty, but, driven before the gale, they are the symbol of force that is irresistible. "His strength is in the clouds!" When the vapoury masses are burnished by the rays of the setting sun, we feel that the Psalmist, in calling them the "chariot of the Lord," has chosen for his metaphor the most gorgeous object that was to be found within the wide limits of the universe.

Thy mercy, O Lord, reacheth unto the Heavens, and Thy faithfulness unto the Clouds. Ps. xxxvi.

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LIGHTNING AND CLOUDS.

O ye Lightnings and Clouds, bless ye the Lord: praise Him, and magnify Him for ever.

LIKE other natural forces, lightning might with propriety have been considered among the "Powers of the Lord;" but, from its being specially invoked, in conjunction with clouds, in a separate verse, we are reminded of the great part it plays in warm climates, and of the beneficent office it performs. Lightning, or Electricity, is believed to be a form of heat; but, whether it be essentially convertible into and identical with other great powers of motion, such as chymical force and life, we need not here discuss. The prevailing theory respecting its nature—one which at least harmonises well with most of the phenomena it presents—is that Electricity is of two kinds, positive and negative; and that these fluids always attract

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each other in order to establish an equilibrium. On the other hand, when bodies are charged with the same kind of electricity—whether this be positive or negative—they repel each other. When a certain amount of the one kind of fluid passes towards the other, it is attended with a flash of light which is termed the electric spark.

We have yet much to learn respecting the work done by electricity in the economy of nature; but, both from its universal diffusion and from the provision made for its production, we may safely assume that the part it plays is most important to the welfare of the world. It certainly exercises great influence in meteorological phenomena—as in the condensation of clouds and rain, the production of currents and storms and the aurora borealis—as well as in regard to the general sanitary condition of the atmosphere. We know how much our health and the comfort of our feelings are affected, even in this country, by the electrical state of the atmosphere; but we can form only a faint idea of the intensity of the inconvenience caused in hot climates where lightning is more common. The thunder-storm, notwithstanding the danger occasionally attending it, is there welcomed as a blessing sent to clear and purify the air, and restore it to its wonted salubrity.

The earth is the great reservoir of electricity,

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and its surface may be considered as a vast electrical apparatus on which the fluid is being constantly developed. When we desire by artificial means to exhibit the presence of electricity, we usually rub glass or sealing-wax with a silk handkerchief, or we cause a plate of glass to revolve rapidly and rub itself against a piece of silk, as in the common electrical machine. So, likewise, in the grand machine of nature, the air is constantly generating electricity as it sweeps or rubs over the earth's surface, and the fluid thus evolved passes back into the earth or into the atmosphere.

The fluid passing into the air may accumulate unduly; and the balance between the atmosphere and the earth being upset, nature steps in and takes means to restore the equilibrium. With this intent, copious rains charged with electricity sometimes draw off the excess to the great reservoir; but when the case is beyond this mode of relief, the firmament is filled with thunder-clouds from which dart the sparks that flash towards the earth. The same kind of action happens when neighbouring clouds are differently charged, and the balance is restored by the passage of electricity from one to the other, as shewn in the vivid sheet-lightning.

There are some substances—such as metals and water—that are called "good conductors," because electricity passes easily through them; and there

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are other substances—such as glass or dry air—that are called "bad conductors," because electricity passes through them with difficulty. In running off through the former the fluid seems gentle and manageable; but in forcing a passage through the latter it tears and destroys. Thus the wire which conducts into the earth the discharge of an electric machine may be held safely in the hand. The fluid will pursue its easy course through the wire to the ground, and will not turn aside to enter the hand and give a shock to the body by forcing its way through so bad a conductor. On this simple fact depends the principle of the lightning-rod. In its flight towards the earth the lightning will avoid a bad conductor, and select a good one, if it is to be had; and thus it will spare the house or the tower so long as there is a sufficient iron rod attached through which it may descend to the earth. In this way the electric discharge, which would have shattered the "bad conducting" tower, glides easily, gently and safely past it into the ground. Formerly people dreaded to enter a smith's forge during a thunder-storm; but now, being better informed, they wisely direct their steps towards it, well knowing that they cannot be in a safer position than when surrounded by masses of iron, that is, with good conductors in contact with the ground.

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As there are comparatively few places which can be artificially protected by lightning-rods, Providence, ever wise and kind, has made various natural arrangements to diminish the danger by which we should otherwise be surrounded during every thunder-storm. Thus it so happens that water, whether in the form of liquid or of vapour, promotes the conducting qualities of bodies. How fitly, therefore, in this Hymn has lightning been associated with clouds! Out of the clouds comes the danger,—out of the clouds, too, comes the water which helps to avert it from us. Dry air is a bad conductor, and favours undue electrical accumulations; but moist air is a good conductor, and drains the fluid harmlessly from the atmosphere. Each big, round drop of rain, as it falls, becomes freighted with some of the superabundant electricity, and carries it off in safety to the earth. The falling torrent, moreover, soaks house and tower, tree and shrub, coats and other vestments, and thus adds to the facility with which they conduct the fluid harmlessly from the air. If caught, therefore, in a thunder-storm and drenched to the skin, let us console ourselves with the thought that we are thus much safer than we were a few minutes before when our clothes were dry.

These means of safety apply chiefly to the thunder-storm itself—to the time when, an undue

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accumulation having occurred, the balance must be redressed even at the cost of danger. But Providence has not forgotten to take precautions by which undue accumulation, though not absolutely prevented, is at least rendered infinitely more rare than it otherwise would be had no such arrangement existed. The world is, in point of fact, studded all over with safeguards against disturbance in the electric equilibrium between the atmosphere and the earth. On this subject a recent writer has well observed that "God has made a harmless conductor in every pointed leaf, every twig, every blade of grass. It is said that a common blade of grass, pointed with nature's workmanship, is three times as effectual as the finest cambric needle, and a single twig is far more efficient than the metallic points of the best constructed rod. What then must be the agency of a single forest in disarming the forces of the storms of their terrors?—while the same Almighty hand has made rain-drops and snow-flakes to be conductors, bridges for the lightning in the clouds, alike, it seems, proclaiming the mercy and the majesty of the Almighty hand."

The Three Children knew well the gladness with which, towards the end of September, the lightning was welcomed in their beloved Judæa. "He maketh lightning for rain," exactly expressed the message which it brought from the sky. It

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indicated that the rule of the scorching sun was drawing to an end, and that the "early rains" were about to fall and refresh the earth, and prepare it for the seed. The practically small danger that might attend the flash was forgotten in the paramount blessing of which it was the harbinger. Yet it must be confessed that, notwithstanding the conviction of its utility, feelings allied to dread attend the explosions of the lightning-cloud; and nothing else in nature brings so home to our minds the conviction that we live in the midst of peril. After every precaution for safety has been taken, what can preserve us from the fatal flash but the ever vigilant hand of God? Lightning seems to be the very type of those messengers of "sudden death" from which we pray the Good Lord to deliver us. The close air that precedes the storm stifles and depresses. Dumb creatures stand anxiously about, utter their cries of fear, and seem to recognise instinctively that the forces of nature are in conflict. The clouds advance, roll up together, and thicken into lurid masses. The sun is walled out from the earth, and something less dark but more oppressive than the night lies heavily upon us. The dart we see cleaving through the blackness is winged with destruction; its course is wild and uncertain, its stroke is sudden, the death it deals is instantaneous. The sounding of the thunder is

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awful. From its lowest mutterings, scarcely breaking on the ear from afar, up to its loudest crash it is ever portentous, and no human heart can listen to it without emotion. The voice speaks to all, and it brings a double message:—it tells us that death is in the air; but it also recalls to us the thought that our lives are in God's keeping, without whose will the lightning cannot hurt us.

Nevertheless, though I am sometimes afraid, yet put I my trust in Thee. Ps. lvi.

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SHOWERS AND DEW.

O ye Showers, and Dew, bless ye the Lord: praise Him, and magnify Him for ever.

THE prominence given in this hymn to water in all its forms is very remarkable, but is easily understood when we recollect that the Three Hebrews were chiefly familiar with "seasonal" countries. Such districts are strikingly and visibly dependent on the timely supply of Dew, Rain, and River water, to preserve them from the effects of the excessive droughts which usually set in at certain periods of the year. We read in Scripture of the "early" and the "latter" rain. The early or, as it was sometimes called, the "former" rain began to be abundant in October, and continued to fall more or less until Christmas. It then either ceased altogether, or became very moderate until spring, when it once more poured down copiously as the "latter" rain.

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The husbandman profited by the first of these periods to sow the seed which was to germinate and stand the winter; while the time that followed the "latter" rain was equally favourable to the rapid growth and ripening of the harvest. If few showers fell at those seasons, the hopes of the husbandman for a good crop were sure to be disappointed, for then, as now, little or no rain was to be expected during the summer.

There are few natural objects more frequently used as symbols in Scripture than rain and dew, and they invariably represent what is good and beneficent. The most blessed of all events—the coming of the Saviour—is thus foreshadowed by the Psalmist,—"He shall come down like rain upon the mown grass; as showers that water the earth." On various occasions rain represents the Creator's benignity towards man; while the force of the expression in Deuteronomy, chap. 32, "my doctrine shall drop as the rain," is derived from its enriching and life-giving virtue.

Besides bestowing fertility on the soil, rain cleanses and purifies both the land and the atmosphere. From the latter it often safely conducts the electricity which is accumulating unduly, and by thus restoring the equilibrium between the air and the earth renders the thunder-storm unnecessary. Rain also relieves the air of some of its superfluous

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carbonic acid, which it hands down to the rootlets of the plants; and, by means of its admixture with this acid, the surface water is enabled to take up a certain quantity of lime, which it transports down rill and river into the sea to furnish myriads of creatures with materials out of which to build their shells. Rain sweeps down into the plains the weather-worn particles of rock which are to form new soil; and, while it washes the surface of mountain and valley, street and house, it increases the general salubrity by clearing off the minute rubbish of the world.

When we consider the enormous volume of water which every year is rolled down into the sea by the rivers and rivulets of the earth, it is not to be wondered at that the annual rainfall which feeds them should be computed to have a bulk equal to 186,240 cubic imperial miles. If spread equally over the land of the globe—50 million square miles—this rain would cover it with water to a depth of three feet. All this huge mass of water comes originally from the ocean, whence it is lifted up into the atmosphere by the agency of evaporation; and as the southern hemisphere has a water-surface of 75 millions of miles, while that of the northern is only 25 millions, it follows that there is a much greater quantity sucked up on the south than on the north side of the Equator. As

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it is chiefly for the sake of the land that rain may be said to fall, and as the land so greatly predominates in the northern hemisphere, it might at first sight appear that Nature had for once committed a blunder in thus making the greatest provision for rain in that hemisphere where, from the comparative scarcity of land, the smallest supply is needed. But on looking more closely we shall see that everything is harmonised through one of those marvellous adjustments by which the whole economy of the universe is characterized.

A supply of water greater than what is locally required being thus drawn up into the atmosphere lying over the southern ocean, the problem is how to convey it into the northern hemisphere, where the chief masses of land lie, and where more rain is needed than can be obtained by evaporation? The machinery used in this gigantic task is found in the great atmospheric currents, which, though subject to occasional disturbance, do yet in the main act with perfect regularity. The chief evaporation from the southern ocean takes place when the sun is to the south of the Equator, and therefore when winter reigns in the northern hemisphere. At this season, the cold in high northern latitudes is most intense, and the heavy air has naturally its greatest tendency to pass towards the Equator. The air thus displaced over the southern ocean

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rises, charged with heat and moisture, into the upper regions of the atmosphere, and there forms a current whose general direction is northwards, or contrary to the polar current beneath it. By this circulation of currents not only is the equilibrium of the air itself maintained, but a most necessary distribution of water and heat is likewise effected. One part of the globe which has an abundance is made to give to another part the supplies that are naturally wanted. Thus we can fancy the atmosphere to be a mighty ship indefatigably carrying on the beneficent commerce of Nature. Setting out from the bleak north, she sweeps round the earth to the regions of the south, refreshing them with cool, dry air; and then, having laid in her cargo of heat and moisture, she starts without delay upon her return voyage, dispensing as she goes the blessings of warmth and rain.

The cause of this regular precipitation may be readily understood by what has been said in regard to Clouds. The tropical air, as it travels north, becomes colder and colder, and therefore its capacity to hold moisture becomes less and less. Hence it is forced at every stage to let go, in the shape of clouds and rain, the excess of moisture which it can no longer hold in solution; and as every drop of rain, on being condensed from invisible

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vapour or steam, gives out as much latent heat as would raise by one degree Fahrenheit the temperature of 1030 drops of water, a powerful influence in moderating the rigour of northern climates is exerted. The last remnants of moisture are squeezed from the air by the hard grip of the polar regions, where, as snow or ice, it adds to the desolation of those high latitudes. To any one contemplating the great arctic glaciers it must be curious to think, that much of the water there piled up in ice has been sucked up amid the warmth and sunshine of the distant southern ocean. The quantity of water thus carried and of heat thus diffused by the agency of the atmosphere almost exceeds belief, and ranks the operation among the greatest of those physical contrivances by which the welfare of the world is maintained. Wonderful Power of the air—working day and night, noiselessly, invisibly—mighty link in the water-circulation of the globe—"dropping fatness" over the earth, and with unerring instinct giving to it from year to year the exact supply that is needful.

In tropical countries, where a hot temperature prevails, a proportionately large allowance of rain is needed for vegetation. Notwithstanding the liberal supplies sent off towards north and south, enough is provided through the great capacity possessed by warm air for holding invisible vapour

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in suspension; and, when rain does occur, the quantity of water condensed is larger and the downpour heavier than in climates lying beyond. From this cause the annual rainfall also is usually much greater. By way of comparison it may be stated, that while the average rainfall of Great Britain is nearly 28 inches, that of the Equator, according to Humboldt, is 96 inches. In some parts of South America and elsewhere this amount is greatly exceeded. At Maranhao, in Brazil, the rainfall has been estimated at 280¾ inches. At Cherraponjie, in India, the enormous quantity of 605¼ inches have been known to fall during the south-west monsoon, which gives to this place the distinction of probably having one of the wettest climates in the world.

Within the tropics the year is divided into the dry and the rainy seasons. The dry corresponds to the winter of higher latitudes, during which plants take their annual rest. In the rainy season showers and sunshine alternate, and vegetable life is stimulated into its most luxuriant growth. The vegetation of warm countries, being habituated to abundant moisture, feels with corresponding severity any material diminution in the supply. Thus, at Bombay, the annual average rainfall may be taken at 80 inches; but in 1824 not more than 34 inches fell—an amount not differing much from

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our own yearly supply—and the consequences were direful famine and pestilence.

He whose lot has been cast in a temperate climate, where showers and sunshine chase each other throughout the year, can hardly realise the eagerness with which the return of the rain is longed for in seasonal regions. Listen to "old Indians" describing the anxiety with which they have watched for the coming of the monsoon, and the ecstasy with which they have hailed its arrival. Some friends may be gathered together within doors—languid, drooping, and spiritless. The drought of the preceding dry months has almost desiccated them. Every exertion is a trouble and thinking a fatigue; everything around pants and fades. Suddenly—not the sound, but—the smell of the coming flood is sniffed in the air. Eyes brighten, muscles begin to be braced, the brain resumes its energy, and in a few minutes afterwards—splash and patter—the rain is once more dashing to the ground. Tanks, buckets, jugs—anything that will hold it—are spread out to be filled with the precious element. Not many hours elapse before the parched earth responds, as if by magic, to the blessing, and with renewed vigour clothes itself in green.

Some of the districts inhabited by our cousins in Australia are liable to suffer from extreme

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drought, when the river courses dry up and the herds run the risk of perishing. In many places it would seem as if Providence had designedly mitigated this climatic evil by means of the deep hollows or wells which occur so frequently in the course of the streams. Thus the general bed may be dry, but these natural tanks continue to hold a supply of water; and, as if still more plainly to indicate their beneficent design, the surface of the reservoir itself often becomes covered with a thick coating of vegetation, which, by interposing a screen between the water and the sun, tends to prevent loss by evaporation.

Rain is so linked with fertility as almost to be synonymous with it, and where none falls there the desert must be. The exceptions to this rule are rare, and even these are seeming rather than real. Thus Egypt may be described as a rainless country; but the inundation of the Nile stands in the place of rain, and, in covering the land with its rich waters, deposits a soil of surpassing fertility. Egypt could no more be fertile without water than other countries, and of this the proof lies close at hand, for immediately beyond the line of inundation the desert begins. The rains which enrich Egypt actually fall in Abyssinia, whence they are conveyed by the Nile as if by a channel of irrigation. The great deserts of the world are em-

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phatically the rainless districts, and they stretch in an almost continuous belt across the centre of the old world. Beginning to the south of Morocco, not far from the Atlantic, they traverse wide regions lying beyond Algiers and Tunis; they next cross Egypt into Arabia; and thence passing onwards through Asia by the great deserts of Tartary, Thibet, and Mongolia, they cease not until they have almost touched the shores of the Pacific. The moisture originally existing in the winds which blew from the sea towards these deserts has either been expended before the winds reached them; or, if a portion of the moisture still remain in the atmosphere, it is from local heat and dryness carried across their surface without precipitation. Let us take the desert lying to the north of the Himalayas as an illustration. During the winter half of the year the prevailing wind blows from the north and east. Being cold, it has little "capacity" for moisture; in other words, it is a dry wind; and as it travels south and gets warmer, its tendency is rather to absorb moisture from the sand than to let it fall. During the summer half of the year, on the other hand, the prevailing wind is from the south-west. Loaded with vapour gathered from the Indian Ocean, it sweeps over Hindostan, dropping rain abundantly in its course; and then, in crossing over the snowy ridges of the Himalayas, most of

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the remaining water is condensed out of it;—the monsoon sponge has been squeezed nearly dry. In this state it descends upon the plains of the desert; where the sand, heated as in an oven by the summer's sun, is not in a condition to draw down the remnants of moisture still existing in the air, and so they pass onward to the north. Thus no "fatness" is dropped upon those sands, which are surely doomed to barrenness so long as the present cosmical arrangements continue.

How many there are who thoughtlessly cry out against the climate of this favoured land, and forget to weigh its many advantages against its few drawbacks. In regard to heat and moisture, it may be said with truth, that we are equally removed from extremes. We neither bake in the sun nearly all the year round, like the children of the desert; nor are we drenched in ever-falling rain, like the Indians of western Patagonia; neither are we dried up for one half of the year, and soaked in rain during the other, like the people of many tropical countries. With us, on the whole, rain and sunshine are well balanced; while the frequent changes enhance our perception of the beauty and the services of both. To our frequent, but seldom persistent, rains we owe it that nowhere is verdure finer, and that in few places is it less exposed to the destructive influences of extreme drought. Even in gloomy

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winter, when rain sometimes falls more abundantly than is consistent with comfort, there is consolation in the thought that the rain which descends at that season of the year, escaping the devouring rays of the sun, will sink deeply into the soil and fill the ample reservoirs of the earth with water. Thence, in the coming days of the hot summer, it will issue bright and sparkling to feed the springs and rivulets that glisten over the land and delight us with their freshness.

Dew may be considered as a kind of supplemental rain, depending on the same cause, namely, a condensation of moisture from the atmosphere. There is, however, this difference between them, that, while rain is formed at a greater or less height in the air, dew is formed on the surface of the ground.

We need scarcely remind the reader that air—even the dryest—always contains invisible vapour. During the day the earth and the air correspond sufficiently in temperature to prevent precipitation. But as the sun begins to set the earth, losing its heat by radiation, suddenly cools, and condenses out of the air in contact with it a portion of its invisible vapour. Hence the night dew. After dawn the returning sun, by again warming the air, enables it to take up moisture; and then the land, having still the coldness of night upon it, immediately

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condenses this vapour into water. Hence the morning dew.

Whatever favours the rapid cooling of the earth's surface promotes the formation of dew. In cloudy weather heat is radiated as usual from the earth after sunset, but it is intercepted by the clouds, and radiated back towards the earth. The temperature of the latter, therefore, does not fall so much, and little dew is formed. But in clear weather the earth rapidly radiates its heat into space, and there are no clouds interposed to radiate it back. Hence the earth cools quickly and much dew falls.

When gardeners cover up their plants on bright evenings they act in accordance with scientific principles. The matting prevents radiation from the earth; or, rather, the matting takes the place of clouds, and gives back to the earth much of the heat it receives. In this manner the atmosphere round the plants retains an equable temperature.

Dew is twice specially introduced into the Benedicite, from which we may infer the extreme importance attached to it in the countries with which the Three Children were familiar. In most parts of western Asia little rain falls from April to September, and during this long period of drought the earth is dependent upon dew for the scanty supply of moisture it receives. How providential

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that, by the ordination of the All-wise Creator, dew should be most abundant precisely at that season of the year when the supply of moisture from other sources is most apt to fail. Scripture abounds in allusions to dew which, like rain, is always associated with what is good and beneficent. The "dews of Hermon" blessed the land where they fell, and the prosperity they brought passed into a proverb. When a patriarch wished to bestow his blessing, he prayed that "God might give of the dews of heaven;" on the other hand, there could be no more withering curse than what was implied in their withdrawal. "Ye mountains of Gilboa, let there be no dew, neither let there be rain upon you."

Although the quantity of water which is annually deposited as dew in this country is small in comparison to the rainfall, still it is by no means inconsiderable. Dr. Dalton has estimated it at five inches, or more than 22 billions of tons of water. In our moist climate it is naturally of less importance than in Syria or Mesopotamia; nevertheless it is extremely serviceable, and in autumn, more especially, the grass would often wither were it not for its daily steeping in dew.

From what has been said it will be perceived that, though we commonly speak of dew "drops," dew does not really "drop" from the sky, but forms

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upon the surfaces where it is found. Yet which of us would consent to surrender an expression that has been endeared to us by familiar associations since childhood? Dew "drops" create for us the most perfect diamond-gardens in the world. Well may they challenge not a lenient but a rigorous comparison with their rivals. No diamonds could be brighter, more sparkling, or play more fancifully with the rainbow colours of light. How incomparably finer, too, the setting! The rare and costly mineral is mostly to be seen in the worn atmosphere of crowded rooms, and, like an artificial beauty, requires the skilful hand for its display. Its brightness pales before the light of day, and needs the garish lamp to stimulate its sparkling. But the diamonds of the garden or the meadow are perfect from nature's hand. They are set with boundless profusion on a ground of choicest green, and no art can improve their new-born loveliness. They are to be seen only in the fresh air of the morn, and the light that suits them best is the pure light of heaven.

Thou, O God, sentest a gracious rain upon thine inheritance, and refreshedst it when it was weary. Ps. lxviii.

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WELLS.

O ye Wells, bless ye the Lord: praise Him, and magnify Him for ever.

IN a song of thankfulness and praise uttered by children of the East to the Giver of blessings, it was to be expected that the "springing wells" of the earth would not be forgotten. Almost always the comfort, and sometimes even the existence of whole communities are there dependent on them. In many districts of south-western Asia rain is scarcely seen from April to September. The "latter rains" which fell in spring have run off, or been absorbed, or evaporated, and the land, thirsty and parched, gathers only its precarious supply of dew. The smaller streams and rivulets are dry also, and the people must then depend on such supplies as wells can

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afford for all the purposes of the household. Hence the prevalence of wells and fountains in the East. In the towns most of the fountains are public; other wells are private property, from which considerable profit is derived by the sale of water in dry seasons.

He who dwells amid the civilisation of the West can scarcely realise the thankfulness with which wells inspire the mind of the Oriental. In the sandy deserts they are of the first necessity, forming as it were the stepping-stones by which travellers direct their route. Districts are named from their wells. Their geological history is often mysterious, but nothing can be more obvious than that they are providentially placed for the purpose of making those wastes passable. The overflow of the well sinks into the sand around, and illustrates in a very remarkable manner the fertilising power of water. The debris of successive vegetations at length creates an oasis of richest soil—an island of verdant beauty in the midst of a sea of sand. The surface is softly carpeted with grass, while date trees and other kinds of palms beckon the traveller towards it from afar, and shade him from the sun. What can be more natural than that the pious Arab should approach those wells with emotions of thankfulness, or that while quenching his thirst he should

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seldom omit to offer a prayer both for him who originally dug the well, and for the generous owner who permits it to be so freely used? It is said that, for the sake of the blessings thus daily poured upon his head, the proprietor of a well can seldom bring his mind to sell it, unless driven by dire necessity to make the sacrifice. To prevent loss by excessive evaporation, as well as choking up by drifting sand, wells in the East are usually kept covered, and so precious is the water that in many instances they are locked also. To poison a well is an act which is considered to be justified only by the extremity of warfare, while its complete destruction is thought to be little less than sacrilege. The well is universally held to be a special gift of God intended for all his thirsty creatures.

. . Holy Scripture abounds in allusions to wells, and nothing better illustrates the importance attached to them in the East from the earliest times than the narrative recorded in the 26th chapter of Genesis. Isaac, forced by famine to leave his country, dwelt in Gerar, and there "waxed great: for he had possession of flocks, and possession of herds, and great store of servants: and the Philistines envied him." Then Abimelech the king said unto Isaac, "Go from us; for thou art much mightier than we. And Isaac departed thence, and pitched his tent in the valley of Gerar, and dwelt there.

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And Isaac digged again the wells of water, which they had digged in the days of Abraham his father; for the Philistines had stopped them after the death of Abraham: and he called their names after the names by which his father had called them. And Isaac's servants digged in the valley, and found there a well of springing water. And the herdmen of Gerar did strive with Isaac's herdmen, saying, The water is ours: and he called the name of the well Esek; because they strove with him. And they digged another well, and strove for that also: and he called the name of it Sitnah," for it was associated with hatred. "And he removed from thence and digged another well; and for that they strove not." It was a contest between those who dug the well and the herdsmen who possessed the territorial right to the water. The possession of a well was the necessary complement to the other means of living, and so long as one could not be obtained the tribe was obliged to move onwards.

The wells that form in the coral islands of the Pacific seem even more strikingly providential than those of the desert. Scarcely has the bare rock risen above the waves before it begins to possess its well of water. The salt ocean is without, and the salt ocean fills the lagoon usually included within, yet, on the mere rim of coral rock that lies between,

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fresh water is to be obtained when a hole is bored. So generally is this understood by sailors that they are in the habit of touching at those solitary spots to fill their tanks. Thus, in the creation of what is soon to be another island added to the fertile area of the world, wells of fresh water are the first provision for the higher forms of life which nature produces. Whence comes this water? The general opinion is, that it freshens itself in filtering through from the ocean; but Darwin, after much attention to the subject, considers it to be the mere surface drainage of the island. In any case, the fact remains as a striking example of providential forethought in thus creating wells for the sake, not only of the traders who casually touch there, but also for the settlers who in process of time come to occupy the island.

Of the rain that drops from the clouds much is at once returned into the air by evaporation to keep up the supply of atmospheric moisture, while much also passes off as surface drainage, battling its way into the nearest brook. But after these demands have been satisfied, there still remains a third portion which sinks down into the porous earth, and commences by subterraneous routes its return homewards to the sea. Imagination longs to be able to follow the course of those mysterious wanderings, and to fill up the gap in the

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history of the spring which is seen bubbling up in the plain from the time when its constituent drops fell among the distant mountains. Through what curious scenery the source of the future river may have been creeping—among what rocks and caverns and windings in the secret paths of the earth—what miniature rapids it may form in regions too deep for human ken—now gliding gently along over rocky plateaus, now lingering among sands, or in the narrow slits of the strata! And thus the rill may journey on until, wearied with subterranean gloom, it regains the light of day as the useful well or gushing spring, nourishing the earth as it flows, and refreshing both man and beast with a constancy of supply which often contrasts with the fitful rainfall.

When it is desired to supply our towns with water we do not rest satisfied with converging upon them the contents of numerous rills by means of an ample conduit. During the hot summer days these sources might dry up, and the people might thus be left in want. So the danger is warded off by storing up water abundantly during the rainy season in a reservoir, from which supplies may be drawn for the town in times of drought. In this manner a liberal allowance of water is securely maintained independently of the vicissitudes of weather. Now in this arrangement we are only

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imitating the wise example of Providence. The town which Nature has to supply is the whole earth. For this purpose the rainfall is undoubtedly her "main," and does the chief part of the work; but rain, though wonderfully regular on the whole, is sometimes capricious in single seasons, and oftener still in the different periods of a season. Something supplementary was, therefore, needed to husband and equalise the supply, and to provide for its regularity independently of the varying rainfall. So Nature formed reservoirs of water in the earth, which, taken on the whole, are subject to very little change. The superficial layers of the crust of the earth are in fact one vast storehouse of water, for moisture pervades them through and through. We habitually speak of "the dry rock," but even the dryest rock contains water lodged in it as in a sponge, of which nothing less potent than the furnace can deprive it. "Some granites," says Professor Ansted, "in their ordinary state contain a pint and a half in every cubic foot." Limestone and marble find room for considerably more. Chalk is also highly absorbent, many of its strata being able to take up half their bulk of water without even appearing to be moist. Ordinary sandstones hold nearly a gallon in a cubic foot, and "in the best building-stones belonging to the sandstone group, from four to five pints of water are con-

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tained in each cubic foot of the stone." "The quantity of water capable of being held by common loose sea-sand amounts to at least two gallons in a cubic foot." But the great tanks of the earth are formed more especially by layers of sand, which everywhere alternate with the harder rocks. Into these the water is constantly soaking and accumulating for the supply of wells and springs all over the world. While rainy seasons fill these reservoirs, the dryest season does not exhaust them; and hence the springs in connection with them appear, like the conduits of a well-supplied town, to be independent both of rain and drought.

Though limestone rocks absorb less than sandstone, they carry the water better; for they are more fissured, and their substance is more easily rubbed away or dissolved by the passing current. By this means, chiefly, have the famous caverns in the limestone rocks of Adelsberg, Derbyshire, and elsewhere been formed. Hence the subterranean rivers found in Styria and in various other parts of the world. No one who has visited the caves at Adelsberg can have forgotten how the Poik, there larger and swifter than the Mole where it joins the Thames, plunges amid the gloom into the tunnelled mountain and is lost. Its course no one knows, but bits of wood and other pilot substances borne along in its mysterious wandering

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proclaim its identity with the Unz, which emerges as a full-formed river at Planina, ten miles beyond, on the other side of the mountain. At Cong in Ireland, famous for its Cross, there is another remarkable example of the same kind, where the river joining Loch Corrib and Loch Mask rushes through a subterranean channel in the limestone rocks. To this tendency in the limestone strata to fissure and separate into ledges which form underground passages we owe what are termed "swallows" in streams. Of these we have an example near London in the Mole, which partially "hides her diving flood" in traversing the picturesque vale of Mickleham; but a much more perfect instance occurs in the wolds of Yorkshire, not far from Malton.

In this moist climate of England a hole dug in the ground usually produces, at no great distance from the surface, a moderate supply of water from the superficial drainage; but such wells are, of course, much influenced by the season, and in periods of drought are apt to dry up altogether. By digging deeper water-bearing strata are reached which are more abundantly supplied, as they represent the drainage of larger districts of country. If these districts lie no higher than the place where the well is sunk, the water will not rise so as to fill the shaft; but, on the other hand, if the water has

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flowed down from higher districts, it will, under certain circumstances, rise in the well to the surface, or even above it, to a height in proportion to the level where it originally fell. It is believed that the Egyptians and Chinese were practically acquainted with this fact at a very remote period, and the excavations that can still be traced attest how extensively they turned it to account. Of late years this mode of obtaining water has been largely adopted in Europe, and the name Artesian has been generally applied to these wells on account of the success which attended the earliest efforts made at Artois. Of all the wells of this kind the most famous is that of Grenelle, near Paris.

Geologically considered, Paris occupies a site very similar to that of London. The shaft at Grenelle, therefore, first pierced through layers of clay, gravels, and sands such as we are familiar with round our own metropolis, and then through the chalk, until it reached the underlying Green Sand. In the spongy strata of this formation vast quantities of water had accumulated by constantly draining down into it, as into a cistern, from extensive higher-lying districts beyond the chalk. The lateral pressure upon the water in this immense tank was therefore enormous. Its floor was formed of impervious clays or rocks, while it was shut in above by a thick lid of chalk.

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The moment the lid was tapped by the borer, up rushed the water as if through the pipe of a water-work, reaching not only to the surface, but spouting into the air to the height of 120 feet. The supply was at the rate of a million gallons a day. There are many Artesian wells in London; but the water is obtained from the more superficial strata lying above the chalk; and as the water, therefore, does not in most cases rise nearly to the surface, it has to be aided or lifted up by supplemental pumps. Artesian wells are also common in Liverpool, in the new red sandstone, at Cambridge, where the water-bearing strata lie under the gault, and in many other places.

Now and then it happens that Nature taps these high-pressure water-boxes for herself, and the stream rushes up through a "bore" of her own making with a force that projects it into the air. In the case of the famous Geysers in Iceland the projecting force, as pointed out by Sir C. Lyell, is due to the pressure of steam acting at intervals, somewhat in the same way in which the steam that accumulates under the lid of a kettle forces the boiling water with violence through the spout. Occasionally the force may be of a somewhat mixed kind, as in the case of the Sprudel at Carlsbad. Although the height to which that fountain spouts is not great, the gush of water is large; while the accessories of

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scenery are such as to produce one of the most beautiful and interesting sights to be found in Europe.

The water that sinks into the earth on higher levels, after collecting into tricklings, and wandering through chinks and over ledges, is ultimately turned by some impenetrable obstacle towards the surface, where it breaks forth as a sparkling fountain. In no fairer shape does Nature spread out her water-treasures before us. How refreshing the draught thus obtained at first hand! How cool in summer, how temperate in winter, for it comes from those deep regions of the earth which are equally shielded from sun and frost. What a difference there is between the tame water of the "main", and the living crystal of "the source". Such a spot is well worthy of a pilgrimage, and adds a fresh pleasure to the summer day's ramble. It is like repairing to a garden to eat fruit newly plucked by one's own hand from the tree. What sight more tempting when the sun is high. How pleasant to play with the clear water, and how difficult to pass before a gushing spring without lingering for a moment to listen and to look!

Springs sometimes partially tell the history of their own wanderings when they assume the character of "mineral waters". The rain that has fallen often becomes charged with carbonic acid gas from

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the air, or from the vegetable soil through which it percolates, and, having thus acquired the power of dissolving the limestone or the chalk through which it has filtered, emerges into day as "hard" or calcareous water. Occasionally its route has lain among iron-freighted rocks, sands, or clays, and the ordinary strength-giving chalybeate of carbonated iron is prepared ready to our hands. Sometimes the water visits the secret laboratories of the earth, where chymical forces are at work on decomposing pyrites, from which it brings to us iron in a less common form, or in union with sulphuric acid. Or it may absorb the gases formed during these decompositions, and appear to us as the unsavoury but useful sulphur well. Again, its course may lie among the salt-bearing strata of the earth, where the varying kinds of "saline mineral waters" are mixed by Nature herself to benefit mankind. Sometimes the subterranean streamlet may wander into those heated depths where chymical action is forging the materials of the earth into new shapes, or where the internal furnace of the globe imparts to the water a portion of its own warmth; and then the streamlet, turned in an opposite direction, may be urged towards the surface by pressure from below, until it bursts into the world as a "hot spring".

The water of springs and wells is never met

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with in a state of absolute purity, but the slight admixture of foreign substances usually present, while it does not impair general usefulness, is attended with certain special advantages. By distillation pure water can always be readily obtained, and it is then in its most active state. But this very condition, so essential to the chymist and the manufacturer, would diminish the utility of water for drinking and other domestic purposes. Water would then have been prone to dissolve many deleterious substances—such as lead—from contact with which it is difficult to guard it at all times, but on which, in its naturally impure state, it cannot act. Another valuable "impurity" found in water is air, either fixed or common, by which it is rendered pleasant and sparkling as a beverage, while at the same time it acquires the important property of boiling without danger. When water has been carefully deprived of air, it may be heated up to 240 deg. Faht. before it begins to boil, but it is then apt to pass off suddenly into vapour with explosive violence. Let any one try to realise the inconvenience which so unmanageable a property would have introduced into the kitchen and the manufactory. We may here mark with admiration how different qualities, even to the most minute details, have been impressed on substances by the great Creator, with evident fore-

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thought for the comfort and happiness of His creatures.

In considering the fountains of the earth as blessings for which praise and thankfulness are specially due, we must not pass from the subject without more particularly alluding to those healing virtues with which some of them have been endowed. Mineral waters are of the most varied character; and there are, perhaps, few chronic forms of disease against which they may not be usefully employed at one stage or another. Providence, too, ever bountiful as kind, has scattered them profusely over most parts of the world, and thousands upon thousands annually owe to them the blessing of restored health. They are gifts from a source that lies beyond our ken, and modern science with all its progress cannot supersede them. We know to a nicety the constituents of the most famous springs; they have been analysed and imitated most perfectly; but there is a point of difference between the real and the artificial which no art can seize. Nature is a cunning worker, and in her laboratory she compounds the "mineral water" under conditions of which we are ignorant, but from which, nevertheless, are derived special virtues which similar ingredients mixed artificially never acquire. Even in so simple a matter as the manufacture of hot water there is a difference; as

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all may have experienced who have contrasted the comparative pungency of a bath of artificially heated water with the softness of another that has been warmed in nature's own boilers. It is a most singular circumstance that the ingredient to which many celebrated wells are believed to owe their chief efficacy is the virulent poison arsenic. Wiesbaden, Spa, and Kissingen contain that substance in union with iron, and it is also widely diffused in the waters of our own country. Thus may it be seen how skilfully Nature can administer the most active poisons for our advantage. The special virtue lies no doubt partially in the smallness of the dose and the accuracy of the compounding; but much may be due to those unknown conditions under which the mixture is prepared. It might have been expected that mineral waters, in passing among the beds whence they extract their components, would have varied materially by being sometimes strong and at another time weak. But although it is not to be denied that variations do occasionally occur, still it is found that substantially the same spring flows on with wonderfully little change from generation to generation. From this cause arises one chief reason of the safety of their administration and the uniformity of the results obtained from them.

In our own country we have reason to be

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thankful for many famous wells, which, in a general way, may be considered efficacious for all purposes to which mineral waters are usually applied. Thus there are potent chalybeates at Tonbridge, Harrogate, and elsewhere. There are "salines" at Leamington, Cheltenham, Bridge of Allan, and in many other places. We have sulphur wells at Harrogate and Moffat, and hot springs at Bath, Clifton, Matlock, and Buxton. In the olden time, when medicine was in its infancy, when no more skilful physician was to be found than the neighbouring monk, and no better drugs than the simples that grew in the Abbey garden, our ancestors placed unbounded faith in wells, and there was not a county in the realm which could not boast of its famous spring. According to the custom of the time, every well was dedicated to the honour of some patron Saint, and it may be affirmed that more than one name would perhaps have slipped out of the Calendar had it not been preserved in association with those springs. Pilgrimages of a mixed sanitary and religious character used to be made to wells of note, and it is curious to observe to how late a period the custom was kept up. Pennant tells us, that in his time pilgrimages to St. Winifred's Well, at Holywell in Flintshire, had not been entirely discontinued. "In summer," he says, "a few are still to be seen in the water in deep devotion, up to their chins for

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hours, sending up their prayers." How different the feelings with which gay spas, especially on the continent, are visited in these days! Customs no doubt change. There is a time and a place for everything, and the pump-room and the bath seem scarcely suited to religious meditation. Still it must be admitted that in principle, at least, our forefathers were in the right, and that their fervent thankfulness, even though shewn under circumstances that might provoke a smile, was infinitely preferable to our frivolity. Surely the place where an invalid day by day is conscious of the blessing of returning health, ought above all others to be the place where the Giver of health should not be forgotten.

Like as the hart desireth the water-brooks; so longeth my soul after thee, O God. Ps. xlii.

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SEAS AND FLOODS.

O ye Seas and Floods, bless ye the Lord: praise Him, and magnify Him for ever.

WHO is there that does not love to wander by the sea shore? Its varying aspects have suggested to poets some of their finest thoughts; and, when they fail to inspire, they often lead on even ordinary minds to a point not far removed from the line where poetry begins. There are some subjects, indeed, which do a great deal for themselves, and from their own attractiveness are not easily spoiled even though handled clumsily. Thus the common-place flights of fellow-strollers afford on such occasions a pleasure which their intrinsic merit does not explain; but sympathy is a powerful varnish which hides defects and stifles criticism. Poetical ideas, moreover, may lighten up the mind with their own beauty and be thoroughly felt and enjoyed, although, in struggling for out-

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ward expression, they cannot bring together the right words and often deviate into very common prose.

In strolling along the shore we find ourselves surrounded on all sides by objects to interest and admire. The cliff and the sands, the boulder rock and the pebbly beach—each has its charm. The ocean enhances beauty where beauty already exists; and it often creates beauty where, but for the charm which it bestows, there would be nothing to admire. On the open shore the air takes hold of us more bracingly than elsewhere; we realise more thoroughly the healthful consciousness of its presence; the drooping nerves are strung again into vigour, as if watered with its freshness. Here, as in other scenes, Nature has her characteristic sounds with which she regales the listener. The cry of the wildfowl is music to him especially whose path of life lies in the crowded city; and the murmur of the crisp ripple or the booming of the wave falls pleasingly on the ear. There is a world of plantal and animal life spread out before us, and we have only to look and to handle in order to be interested. How precious now are the scraps and fragments of Natural History which we can bring to bear. Nowhere is knowledge more enjoyment-bringing, for nowhere are the arrangements which God has made for the welfare of his humble

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creatures more conspicuous. How swiftly the time flies as we probe and peer into the clear lakelets that gather round the boulders on the sands or in the hollows of the rocks. The eye wanders delightedly among the many-coloured tufts of algæ that clothe their coasts and depths. These miniature forests teem with varied life, and many a little creature finds in their recesses a secure retreat from cruel foes. Stealthily we draw near to those pools, seeking not to destroy but to admire, and feel well rewarded if we obtain but a glimpse of their inhabitants.

Not less pleasant is it to retreat step by step before the returning tide, to lose the dreary sands as they are again covered up in their mantle of water, and to watch the thousand eager streams rushing in from the sea among the rocks, and once more joining on to the boundless ocean the pools we have been surveying. What a change suddenly passes over the black and yellow seaweed! A moment before it lay dingy and motionless upon the rocks, but now, revived as it were into new life by the return of the sea, it begins to float and wave its pennons. The mussels and periwinkles, the limpets and the sea-acorns which, an instant before, were glued to the rocks as faded and dead-like as the stones themselves, now hear the rushing sound and welcome the returning water. In another

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minute these trusting waiters upon Providence will be opening their mouths to the currents which bring them their "daily bread," rasping their food from the tough seaweed with their file-like tongues, or raking in supplies with their handy tentacles. The ever bountiful sea will surely bring nourishment to them all—not one will be forgotten by Our Father.

The eyes of all wait upon Thee, O Lord; and Thou givest them their meat in due season. Ps. cxlv.

The lower depths of ocean are still a mystery, although of late years the diving bell, the dredge, and the plummet have added much to our knowledge both of its bed and its inhabitants. In a general way its bed resembles the land—now rising into mountains, now sinking into valleys, or spreading out into table-lands. The deepest recesses below the level of the sea-surface are believed to be about equal to the height of the highest hills above it; but so inconsiderable is this depth in relation to the diameter of the earth, that a mere film of water laid upon a sixteen-inch globe with a camel's-hair pencil would adequately represent it. It is difficult to say at what depth life becomes extinct; but just as in ascending into the air on lofty mountains there is a limit beyond which nothing living can maintain itself, so in descending into the

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depths of ocean a stratum is reached below which life cannot exist. The life which we know has a frontier downwards as well as upwards. The floor of the Atlantic appears in some places to be a vast sepulchre, for at Telegraph-ridge it was found at a depth of two miles to be completely covered with calcareous and siliceous remains of microscopic animalcules. There the deposit may go on increasing and thickening until, under the vast pressure of the overlying mass, the limestone strata of new continents have been founded. It need scarcely be said that modern observation has completely overturned the gloomy picture of the bottom of the ocean which fancy suggested to Shakespeare, but which, in the absence of all practical data, has stood its ground popularly almost up to the present time. Schleiden says that "we dive into the liquid crystal of the Indian Ocean, and it opens out to us the most wondrous enchantments of the fairy tales of our childhood's dreams." The Professor's description is too long for quotation here, but it introduces us to sub-marine scenery where "strangely branching thickets bear living flowers. The colouring surpasses everything: vivid green alternates with brown or yellow: rich tints of purple, from pale red-brown to deepest blue." "There are Gorgonias with their yellow and lilac fans, perforated like trellis-work: leafy Flustras adhering to the coral

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branches like mosses and lichens: yellow, green, and purple-striped limpets resembling monstrous cochineal insects upon their trunks." "Like gigantic cactus-blossoms sparkling in the most ardent colours, the sea-anemones expand their crowns of tentacles upon the broken rocks, or more modestly embellish the flat bottom, looking as if they were beds of variegated Ranunculuses. Around the blossoms of the coral shrubs play the "humming-birds" of the ocean, little fish sparkling with red or blue metallic glitter, or gleaming in golden green or with the brightest silvery lustre." The many-tinted phosphorescent lights of the ocean crown this gorgeous painting, and "complete the wonders of the enchanted night." "The most luxuriant vegetation of a tropical landscape," continues the Professor, "cannot unfold as great wealth of form, while in variety and splendour of colour it would stand far behind this garden landscape, which is strangely composed exclusively of animals, and not of plants. Whatever is beautiful, wondrous, or uncommon in the great classes of fish and Echinoderms, jelly-fishes and polypes, and mollusks of all kinds, is crowded into the warm and crystal waters of the tropical ocean."

The abundance of animal life in the ocean greatly exceeds that on land. The sea affords a home for the largest of known animals as well

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as for the most minute: life teems everywhere. Scoresby once sailed through a patch of the Greenland sea—20,000 square miles in extent—covered with a species of medusa on which the whale feeds, and he calculated that every square mile contained 23 quadrillions 888 trillions of independent living creatures! He did his best, moreover,—we shall not pronounce with what success,—to bring the number contained in one of these miles within the range of our conception by saying, that "to count them would require 80,000 persons, and a period equal to the interval between the present and the creation." Yet it must be recollected that this was only the aggregate of life in one of the 20,000 square miles, and that the whole scene was but a mere fragment of the ocean. Such numbers are incomprehensible, but even viewing the statement as metaphorical it conveys a lofty idea of the profusion of marine life. In the coral polyp we have another example of a creature whose numbers equally baffle our conception. In many parts of the ocean, islands and reefs are now being constructed by countless myriads of these animals. Off the east coast of Australia there is a single coral reef a thousand miles long, and vast tracks of the Pacific are studded with islands of coral formation. Placed side by side with the productions of these pigmy labourers, our pyramids and breakwaters,

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and the most stupendous works reared by man sink into utter insignificance.

It is noteworthy that amidst this richness of life the sea, like the land, has its deserts—"desolate regions," as they are termed by mariners—in which few signs of life in air or water are to be seen. In many maps such a region will be found laid down in the South Pacific, between Patagonia and New Zealand. Birds that have followed a ship for weeks together seem to recognise this blighted ocean-desert, and fall away as soon as they enter it.

The blue colour of the sea is one of its chief attractions, and, as the intensity is greatest where the saline matters are most abundant, there would appear to be a close connection between the two conditions. Thus the water of the Gulf-stream, south of Newfoundland, is bluer than the fresher water beside which it flows, and the line of demarcation between them is so sharp as to be easily distinguished. "Off the coast of the Carolinas," says Maury, "you can see the bows of the vessel, as she enters the Gulf-stream, dashing the spray from those warm and blue waters, while the stern is still in the sea-green water of the Bank of Newfoundland." The "blue Mediterranean" has become a proverb, and the fact is explained by the circumstance that the sun, by causing enormous

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evaporation, strengthens the brine of its confined waters as in a salt-pan. On the other hand, seas that contain comparatively little salt, such as the German and Arctic oceans, are of a green rather than a blue colour. By this easy test it is said that manufacturers of salt sometimes judge of the richness of the water.

Navigators tell us of other colours which the sea exceptionally assumes. Thus there is a Yellow sea, called so from the colour of the sand, or mud; a White sea, from the weakness of the saline solution; and a Red sea, from slimy fuci cast up from the bottom of its bed. Near Tierra del Fuego Darwin observed patches of a brown-red colour, produced by prawn-like crustaceans floating in it. The sailors called them whale-food; and, in truth, they appeared to be just the sort of banquet on which a whale would feast. Near the Galapagos Darwin also remarked that a film of floating spawn gave a dark yellowish or mud-like colour to the sea; on another occasion the ocean was covered for miles with a coating that displayed iridescent colours. The sailors, who are often shrewd observers, attributed it "to the carcase of some whale floating at no great distance." A patch of white water, twenty-three miles in extent, was observed in the Indian ocean. "In appearance," says Darwin, "it was like a plain of snow." "The

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scene was one of awful grandeur; the sea being turned to phosphorus, the heavens being hung in blackness, and the stars going out."

Phosphorescence is one of the most beautiful appearances presented by the sea. We sometimes fancy it to be very vivid upon our own coasts, but sailors nevertheless assure us that the light is pale in comparison to the brightness with which it shines in tropical regions. There are two forms in which it appears. In one, bright isolated specks are seen from the shining of star-fishes, annelids, medusae, and various kinds of crustacea and mollusca. In the other, there is a diffused luminosity, often flashing into coruscations, which is produced by a profusion of microscopic animalcules. The phosphorescence of the Noctilucae is sometimes beautifully seen while steaming along our coasts at night, as the water is dashed from the bows, but it is also very conspicuous when a glass vessel, filled with water containing them, is placed in the dark. These creatures occupy one of the humblest positions in the animal scale. Yet, though they look like mere specks of animated jelly, they are by no means insensible to rough treatment, under which they shine with increasing light.

If all the salt in the sea were collected together it would cover the entire surface of Europe with a

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layer one mile in thickness. Whence comes this saltness of the sea, and what is its use? The first point is doubtful. The earth, it is true, contains vast stores of salt hidden away among its strata, and in the convulsions through which it has passed the salt might easily have been washed out into the sea. But, on the other hand, the beds of salt found in the earth shew unmistakeably that they themselves have been deposited from water. Not improbably the sea was created salt, just as we now find it; and, from its almost unvarying constitution preserved amid causes tending to disturb the balance, it seems to retain by special ordinance the exact amount of saltness best adapted to the uses it has to fulfil. At first sight it might appear as if this saltness would detract from its utility, for there are few purposes to which it can be applied in comparison with those for which fresh water is suitable. But a little reflexion will shew us that, while there has been no stinting in our supplies of fresh water, the additional gift of salt water has added largely to our resources by properties peculiar to itself. It is thus fitted to be the habitation of countless tribes of fishes and other creatures which afford us most abundant and welcome supplies of food, and brings to every shore the means of obtaining salt which is an essential element of healthy nourishment.

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The ocean is "ever restless." There are interstitial movements between the drops themselves of which it is composed, and there is a grand circulation in the whole mass of water to which the term current is usually restricted.

The necessity for this circulation may be inferred from the care which Providence has taken to insure its efficient performance. Within the tropics the fierce sun is constantly skimming the surface of the sea, and creating a void that has to be filled up by the surrounding water. Among the most powerful agents of circulation is the moon, by whose attraction is raised the wave of the tide, which, setting out from one extremity of the ocean, traverses it unto the other. The willing atmosphere, seldom standing idly by when any of the grand operations of nature are going forward, takes its share of the work, and by its Trade winds, monsoons, and other breezes helps on the good cause. Sometimes the wind churns the waves, as in the storm; at other times it drives them before it, and piles them up in confined bays, such as the Mexican Gulf, whence they fall down as a current across the neighbouring sea, and thus restore the equilibrium. But the mainspring of the machinery is to be found in the ocean itself which, by means of differences in its weight, or specific gravity, establishes the principal currents. In equatorial re-

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gions evaporation thickens the brine, and makes it dense and heavy. In the polar sea evaporation is checked by the cold, while melting snows and glaciers pour into it immense quantities of water during the summer, by which it is made fresh and light. There is thus at one end of the mobile mass a dense fluid, and at the other end a light one; and the necessary result is a circulation from the equator to the poles to displace the fresh water, and a counter-current from the poles to the equator to fill up the void which the dense water leaves behind it. Distance counts for nothing in such a chain, and when one link is moved all the other links must move also. By this means a thorough circulation is effected. On the one hand, the ocean is being continually poured into the polar seas; on the other, it is in an equal ratio emptied back into the regions of the tropics.

The proofs of this "greater circulation" are to be found in many places, but they are less conspicuous in the southern than in the northern hemisphere, on account of there being comparatively so little land between the tropics and the antarctic regions. The polar and equatorial streams are consequently more diffused than in the northern hemisphere, and their force, with few exceptions, is not so great. Towards the north, on the contrary, the channels of communication be-

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tween the equatorial and polar seas are narrower, and the currents, therefore, are more distinctly marked. It is just the difference between a river whose strength is wasted by the width of its bed, and one whose waters being confined within a narrow channel rush impetuously along.

The surface of the ocean is thus mapped out into currents by the constancy of which the navigator profits. But besides these stronger streams there are others whose force is so gentle and diffused that their existence cannot be detected by the reckoning, and is only made known by the thermometer. In pursuing an eastward or westward course across the ocean, an alteration in the temperature tells where the water comes from. Thus, if the temperature increase, it may be inferred that there is a flow from the south; and if the water get colder, a northern origin is equally indicated.

The Gulf-stream is the most famous of all the currents that flow towards the north, and is in itself one of the most wonderful physical phenomena in the world. Its great historian, Maury, thus eloquently describes it:—"There is a river in the ocean. In the severest droughts it never fails, and in the mightiest floods it never overflows. Its banks and its bottom are of cold water, while its current is of warm. The Gulf of

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Mexico is its fountain, while its mouth is in the arctic seas. It is the Gulf-stream. There is in the world no other such majestic flow of waters. Its current is more rapid than the Mississippi or Amazon, and its volume more than a thousand times greater." Rushing past the point of Florida, it starts on its path across the Atlantic as a compact river sixty miles broad and three thousand feet deep, and at a pace of four or five miles an hour. Onward it streams in a north-easterly direction, spreading out its waters like a fan, until it approaches the Cornwall coast, the west of Ireland, and the Hebrides of Scotland. The great bulk of the still warm waters flows onwards between the Shetlands and Iceland; and then, after laving the northern shores of Norway, the current is gradually lost in the Spitzbergen seas. Whether the waters of the Gulf-stream, still recognisable by their temperature, are destined to be re-discovered as an open, comparatively mild sea under the pole, surrounded by arctic deserts that lie outside the influence of this offshoot from the sunny south, is a problem which the next few years will probably resolve.

Side by side with this warm northward-moving flood there is a great polar stream bearing down in an opposite direction, which appears to be more especially its compensatory current. It rises in

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the distant recesses of Baffin's Bay and the Greenland sea, and then, studded with icebergs, sweeps along the coast of Labrador, encircling the island of Newfoundland in its chill embrace. To the south of the Bank it encounters the Gulf-stream running north-eastward;—the paths of the two giants cross each other, and they struggle for the right of way. Their hostile waters refuse to mingle, and each continues to retain its colour and its temperature. But, though neither is vanquished, each leaves its mark upon the other. From the force of the shock the Gulf-stream for a moment falters in its course, and is deflected towards the south; while the polar current, unable to break through the concentrated mass by which it is opposed, dives under the bed of the mighty stream, and hastens on towards the tropics.

The higher latitudes of the southern ocean are even more numerously studded with drifting icebergs than the northern, from which, were other proofs wanting, we might safely infer the existence of currents analogous to those just described. The superficial polar currents are sometimes very baffling to navigators desirous of penetrating into high latitudes. One of them was carried—ship and all—a distance of 1200 miles upon the ice, as it drifted down the centre of Baffin's Bay. Captain Parry, too, found all his efforts to penetrate to-

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wards the pole counteracted by the circumstance that the distance travelled in sledges during the day was only equal to the southern drift of the whole mass of the ice during the night. Under this superficial polar current there is in some places, perhaps in all, a deeper current running in the opposite direction. Thus it has occasionally happened in Baffin's Bay, that while ships in calm weather have been drifting to the south on the superficial stream, large icebergs, whose bases must have sunk deep into the lower current, have been observed to move in the opposite direction.

These currents of the sea aid commerce, distribute seeds over widely distant regions, and sometimes afford abundant supplies of timber to countries destitute of forests. In this way the Icelanders are furnished from the woods bordering the rivers in Siberia. In high latitudes it is obviously important that the sea should remain free from ice as long as possible, both for the sake of commerce and because the Esquimaux find in it their chief stores of food. The saltness of the ocean helps to keep it open; for while fresh water freezes at 32 degrees, salt water remains fluid down to a temperature of about 28 degrees. But the polar seas, from the rains and melting of the ice, combined with the small evaporation going on in them, tend to become less salt; while, at the

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tropics, from the great loss of water by evaporation, the saltness tends to increase. The equatorial current, therefore, assists in keeping the Arctic sea open by bringing to it supplies of stronger brine from the South.

By means of the great currents of the ocean another extremely important function is performed. One of the chief cosmical problems which Nature had to solve was how, on the one hand, to warm the North, and on the other to cool the South, to the degree best adapted for the development of life. For the regulation of the heat account between them Nature has employed the most powerful machinery that exists on the earth. We have already seen how heat, packed up in the vapour arising from southern seas, is borne along by the atmosphere to regions where it is wanted; and we now perceive that this machinery—vast as it is—requires to be supplemented by the heat conveyed towards the poles in the currents of the ocean. The means are marvellously great, yet not out of proportion to the magnitude of the work to be done. Pouillet and Herschel have estimated the daily amount of heat received by the earth from the sun as sufficient to raise the temperature of 7513 cubic miles of water from the freezing up to the boiling point, and of this heat equatorial regions receive a proportion which would be incompatible with life

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did not some contrivance exist for carrying off the excess. Owing to the preponderance of sea between the tropics the ocean of course receives the largest share of this heat. It has a mean temperature of about 80°; while in the Caribbean sea and in some other places the temperature rises nearly to blood heat. Were the water not renewed in the Mexican Gulf, it would soon become destructive to life. To prevent this Nature establishes currents by which some of the hot water is continually drawn off from the caldron, and an equal portion of cold water is continually let in. The operation may be compared to a kitchen boiler fed with cold water through one pipe, and from which a proportionate quantity of hot water escapes through another. The "main" that issues from this tap is the Gulf-stream, and, in order to form some idea of the service it renders, let us consider the amount of heat it carries along. As it leaves the caldron there is a mass of water, 60 miles broad by 3000 feet deep, with a maximum temperature of 86°; and before it is lost in the polar sea its temperature has fallen to nearly 32°. All the heat implied in this difference has been distributed by the way, and has been spent in improving the climate of the regions through which it passed. Maury calculates that the heat discharged over the Atlantic by the waters of the Gulf-stream in a winter's day

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would be sufficient to raise the whole atmosphere covering France and the British Islands from the freezing point up to summer heat; and in another place he says that it would be sufficient to keep in flow a molten stream of iron greater in volume than the Mississippi. There is "a Providence" even in the refusal of the giant streams to unite together off the coast of Newfoundland. By this designed separation "the heat and the cold" are carried better and farther, and the object of the distribution is more perfectly attained. It is indeed remarkable how well heat and cold are thus conveyed. The cold polar current which we lost to the south of the Bank of Newfoundland, where it dipped under the bed of the Gulf-stream, could still be reached by deep soundings, and recognised by its temperature of 35°, while the "river" flowing above it was 80°. And by the same means it is again to be recognised among the West India Islands, with the cold label of its origin still attached to it. In those seas the temperature of the surface water may be 85°, while that of the deep water is 43°, or only 11° above the freezing point. There is another evidence of design about this wonderful stream which must not be passed over. Maury says, "its banks and its bottom are of cold water;" and, indeed, this was essential, in order to make it a good hot-water

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pipe. Earth and rocks are better conductors of heat; and, consequently, if the banks and bottom had been constructed, as they usually are, of these materials, the Gulf-stream would have held its heat with a less tenacious grasp, and could not have carried it, as it now does, 3000 miles across the ocean to improve the climate of cold latitudes. At Newfoundland in winter-time the thermometer is often at zero, while within a good day's sail to the south may be enjoyed the genial climate of the Gulf-stream. Its influence in warming the winters of the British islands is shown by a comparison between our thermometric register and that of places situated on the same parallel of latitude on the other side of the Atlantic. When it reaches Hammerfest, near the northern extremity of Norway, and considerably within the arctic circle, its influence suffices to keep the harbour open in the severest seasons. It is even asserted that, in the ocean near Spitzbergen, water is occasionally to be met with in the track of the Gulf-stream which is only one degree colder than it is in the depths of the Caribbean sea.

From this general outline some idea may be formed of the way in which God has made the ocean currents co-operate with other causes in equalising temperature over the globe. By their means the heat which would otherwise accumulate

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at the tropics is carried towards the poles; while the cold which would oppress the polar regions is, if we may so express it, carried towards the equator. By this beautiful provision the climates of the world are improved; the bleak north is made less bleak than it otherwise would be, and the temperature of the over-heated south is kept within due bounds. In these islands, more especially, we have reason to bless God for the beneficence of an arrangement which softens the rigour of our climate, and gives to some parts of the kingdom a winter season which in temperature may compete with many in the south of Europe. Nor can any one who considers the vastness of these operations fail to perceive how much the Creator is praised and magnified both by the simplicity of the means employed, and the perfection with which the end is accomplished.

The great currents we have been considering form the main arteries and veins of the ocean; but there is also a constant interstitial movement and mixing going on among the particles themselves, which might by comparison be termed its capillary circulation. The dynamic force is derived from local changes in temperature or in the degree of saltness. Every beam of sunshine that falls upon the sea, by altering the specific gravity of the portion on which it falls, sets a current in motion to

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re-establish the equilibrium. In like manner every kind of fish, and more especially every kind of shell-building creature that lives there, as soon as it has absorbed a particle of lime, silica, or other matter, alters the specific gravity of the atom of water whence the matter was extracted, and creates a minute current of denser water to restore the equilibrium. Plants which, like corallines, absorb lime act in the same way. The amount of each operation is infinitesimal, but the grand result is that a capillary circulation of minute currents is everywhere going on, by which the salubrity of the general mass of the ocean is maintained. How wonderful the simplicity of the means by which all this is accomplished. A grain more or a grain less of common salt contributes its share in keeping the ocean in healthy movement! Nor is it to be forgotten that the inhabitants of the sea, by withdrawing lime and silica, prevent these substances from unduly accumulating in its waters. For as all the rivers that fall into the sea are continually bringing saline matters into it, these would soon exist in hurtful excess if no arrangement had been made for their removal.

There are some inland seas of the highest value to mankind, which would ere this have degenerated by evaporation into pestilential swamps, had not the Great Architect insured their safety by

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establishing permanent currents of supply which flow into them from the ocean. The Mediterranean—one of the greatest water-highways of the world—may be cited as the most remarkable example. It is computed that the evaporation going on from its surface skims off no less than three times as much water as it receives from all its tributaries taken together, and it would, therefore, be inevitably dried up were it not fed with a corresponding equivalent of water from the Atlantic. Yet even this arrangement would not of itself suffice to obviate the threatened danger. It is evident that excessive evaporation, besides lowering the level of the surface, would also have the effect of concentrating the brine; and this would go on until, the point of saturation having been reached, layer after layer of salt would be precipitated to the bottom so as ultimately to fill up the entire bed. The purpose of the current from the Atlantic is to provide for the waste by evaporation, but being itself salt it does not tend materially to dilute the brine that remains. A sure remedy, however, is found in that law which governs the universe—gravitation—and thus the saltness which caused the danger, brings also with it the means of safety. For as the deep water in the Mediterranean increases in saltness, it becomes heavier than the less salt water of the adjoining Atlantic, and

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consequently acquires a tendency to fall in upon and displace it, just as a portion of heavy air displaces a contiguous portion that is light. In this way a counter current is established at the Straits of Gibraltar. The superficial current runs in from the Atlantic to maintain the level of the sea that has been lowered by excessive evaporation; and the deep current runs out from the Mediterranean to carry off that excess of salt which, if retained, would in the end convert its bed into an unhealthy swamp.

The Red Sea would have been even in a worse plight but for a similar arrangement. The sun beats so hotly upon it that its waters are often raised to a temperature of 90°; consequently, the evaporation is excessive. On the other hand, throughout its whole length of about 1200 miles not a single stream that can be called a river falls into it. But all is adjusted, and safety is secured by the existence of a double current at the Straits of Bab-el-Mandeb. That which is superficial brings an abundant supply of water from the Indian ocean; that which is deep carries off the excess of salt from the Red Sea.

Another well-known sea—the Baltic—is in danger of losing its healthy amount of saltness from causes the reverse of those just mentioned; for while many rivers bring to it supplies of fresh

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water, it lies so far to the north that comparatively little is dissipated by evaporation. The brine is thus in danger of being over-diluted. The remedy, however, is found in a double current. By the superficial current, some of the brackish water is decanted off into the North Sea; by the deep, a supply of salt is brought from the North Sea into the Baltic.

The tidal floods which add so much to the interest of our seaside strolls are also of the highest utility. Though little else than mere undulations without movement in the open sea—like those we admire in fields of "wavy corn" when agitated by the wind—tides are strong currents in the narrow seas and the rivers where they ebb and flow. Tides, therefore, facilitate commerce; and from their undeviating regularity enter as a certain element into the sailor's calculations. The wave of water thus sent up a river deepens its channel, and gives to many an inland town the advantages of a sea position. But for the tide, the miles of wharves which border the Thames at London would never have existed; and it is not too much to say that to its tide the metropolis owes its rank as the foremost commercial city in the world. At high water the channel at London Bridge is deepened to about 18 feet; while Bristol and Glasgow are even more dependent upon the tide than London. The Avon, at St Vincent's rocks,

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when the tide is at the lowest, would hardly swim a boat; but after it has received its forty feet flood it could float a man-of-war. At Glasgow there are persons living who recollect when the river could be waded across at low water. The height of tides varies extremely. Where there is nothing to confine them, as in the open ocean, they seldom rise above two or three feet; and the same effect happens if the direction of an inland sea lies out of the course of their flow, as in the Mediterranean. On the other hand, where a gradually contracting estuary, like the Bristol Channel, opens fairly to the flood, it sweeps in from the ocean with full volume, and being hemmed in more and more between converging shores it mounts higher and higher as it advances. Thus at Chepstow the tide occasionally attains an elevation of 50 feet. Still more extraordinary is the tide in the Bay of Fundy, on the east coast of New Brunswick, where a wave one hundred feet high is sometimes piled up by the flowing flood. This wall of water advances at such a pace that it often overtakes deer, swine, and other beasts feeding or rambling about the shore, and swallows them up. The swine, as they feed on the mussels at low water, are said to smell, or perhaps to hear, the "bore" while it is yet distant, and sometimes dash off at the top of their speed to the cliffs to avoid the coming danger.

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There is something mysteriously melancholy in the first glance which the voyager unaccustomed to ocean life takes from the deck of his ship when it has borne him fairly "out of sight of land." With nothing visible around but sea and sky, he sees his ship a mere speck upon a trackless waste. Yet there is no hesitation among those who guide the noble bark which forges onwards to its destined port. The "pathless" ocean is in fact a mere figure of speech, for its highways and byeways have been surveyed and accurately mapped. On deck is to be seen the trusty compass, pointing out the course, like an attendant monitor, with a finger that never tires. Above, there are the sun, the moon, or the stars—beacons fixed high in the heavens—sign-posts that never deceive the mariner who has skill to read their writing. The accuracy of modern navigation is truly miraculous. Ships start on a voyage of 15,000 miles, say, from New York to California, during which they may not once see land, yet they strike the sought-for harbour as if the goal had been always before their eyes. The late Captain Basil Hall once sailed from San Blas, on the Mexican coast, round Cape Horn to Rio Janeiro. He was at sea three months, during which he saw neither land nor sail, yet he struck the harbour's mouth so exactly that he scarcely required to alter his course by a single

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point in order to enter it. Had God not provided for accurate navigation by means of astronomical signs, and had He not designedly endowed man with special faculties capable of understanding their import, commerce as it is now developed could never have existed; and there is not a nation on the earth which would not thereby have lost many of the comforts and blessings now brought to it. Through His beneficence the "pathless ocean" has become the world's greatest highway; and, instead of separating nations, it joins them together. It is easier now to reach the remotest corner of the globe by sea, than it is to penetrate into Siberia or Arabia, though these countries lie comparatively close at hand.

The sea is slightingly called the "unstable element," but in the permanence of its condition it is much more stable than terra firma. The land is in some places being heaved upwards, in others it is sinking downwards; but the level of the ocean never changes. Sometimes the sea is hastily identified with "treachery," but its currents are more trustworthy than the winds on land. True it is that, in obedience to the law of gravity, a ship sometimes sinks and a gallant crew perishes. But upon the upholding of this very law of gravity every other life in the world depends, and its suspension even for an instant would involve universal de-

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struction. The sea sometimes bursts its bounds and desolates the dry land, or sweeps the useful pier into the deep, or destroys the lighthouse; but God has given us faculties and provided us with means to grapple with all these evils, and control even the ocean itself. Man's industry and skill again shut out the sea with stronger dykes, he builds a better pier, rears another lighthouse round which winds and waves dash in vain, and he plants the solid breakwater athwart the deep to create the safe harbour within. Thus some of man's greatest victories are won in his battles with the sea. Modern skill in building and in navigating ships has reduced the dangers of the sea at least to a level with those of the land, and has in most cases made ocean disaster synonymous with ignorance or want of care.

The great rivers of the earth are preeminently its Floods, and the harmony with which rivers and ocean are regulated in relation to each other is another marvel of creative adjustment. "All the rivers run into the sea," saith the Preacher, "yet the sea is not full." Great as are the volumes of water poured into it by rivers like the Mississippi, the Amazon, the Nile, the Ganges, the Yang-tse-Kiang, as well as by every stream and rivulet throughout the world, the ocean knows no change, but preserves its level with

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a constancy which geologically distinguishes it from the land. The supplies of water poured into it from every source have been measured by the Creator with a nicety which satisfies all wants but leaves no surplus. With the same exactness the rivers throughout the world are fed with a uniform supply. In certain years, or at certain seasons of the year, the level of their channels may vary; but, notwithstanding climatic disturbances, the freaks of the rainfall, the dry and wet years, the irregular melting of the snows, and other causes, the great rivers shew no sign of change in the amount of their annual tribute to the ocean. The streams that feed them may change; they may dry up at one season or be swollen into torrents at another; but ultimately an average balance is struck, and thus the mightiest rivers, like the Amazon, take little note of such disturbances. The Nile at first sight seems an exception to this rule, but the exception is apparent rather than real; for the Nile, when the mean between its lowest and highest state is taken into account, probably varies as little in its yearly average as other rivers. Thus may it be seen how that most gigantic and wonderful of all hydraulic machines—the atmosphere—does its work to perfection. By evaporation it yearly lifts up from the ocean the quantity of water that is needed by the land; and it pours into the channels of the rivers a

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supply which from year to year scarcely knows variation.

The great inland seas of the globe present to us features which illustrate even more strikingly the power and wisdom of God. Look at the Caspian and the Sea of Aral in Central Asia, or at the Great Salt Lake of North America. Each of them receives the drainage of a large district, and yet there is no outgoing stream to carry off the water. If we were to continue pouring water into a basin we know what would happen;—the basin would be filled to the brim, and would then overflow. And in like manner the water in these inland seas would overflow and devastate the country had not a safety-valve been provided in evaporation. But again, the evaporation might have been too little or too much. It might not have been sufficient to correct this tendency to overflow; or it might have been excessive, so as ultimately to have sucked the sea dry, and left its bed an arid, salt-encrusted desert. But no such blunders are to be found in Nature's operations. The waste on the one hand, and the supply on the other, are so exactly adjusted as to equalise each other, and thus the level of those inland seas is for the most part preserved. In some districts of Asia, however, are to be seen what may be called the ruins of ancient seas, which, in the all-wise plans of Providence, were not intended to

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endure. In them the moisture was in the course of years dissipated by evaporation; the brackish water thickened into brine, and the brine solidified into salt-encrustations which mark the site of the the old bed.

Another evidence of providential design is seen in those lakes which so frequently spread themselves out near the chief sources of rivers. In the language of physiology they might justly be called "diverticula," since they are reservoirs in which water that is in excess is stored up until it is wanted. If there were no provision of this kind, inundations from the rapid rise of torrents during heavy rains would occur more frequently, but by the aid of these natural reservoirs the storm passes over in safety. A great portion of the rain, instead of running off at once in violent floods, accumulates in the lake, whence it is given out gradually and profitably, and thus often suffices to keep up a flow of water when drought might otherwise have left the river dry.

Rains, rills, and rivers alike rasp off the surface of the globe as they pass over it or through it. The rubbings of the rocks go to increase the store of fertile soil. As earth or mud they are washed along by the current, and deposited over the slopes and plains. Sometimes, from peculiar causes, inundations periodically occur, as with the Nile in

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Egypt, whereby, after subsidence, a rich coating of fertile soil is found deposited over the surface of the land. Most great rivers transport to the sea enormous quantities of earthy matters and gravel, which in the course of ages form round their mouths a "delta" or projecting tongue of rich alluvial soil. Besides these more bulky matters, rivers bring down into the sea supplies both of lime and silica, which they have dissolved out of the soil or the rock. With such materials of ocean architecture myriads of fishes, mollusks, polyps, and other creatures obtain all they require for the growth of their skeletons, the building of their houses, and the construction of those mighty reefs of coral which are slowly rising like new continents from the deep.

In Holy Scripture we are not less struck with the beauty than with the exactness of expression in which some of the leading points connected with the water-system of the globe have been described. In Ecclesiastes the sea is recognised both as the beginning and the ending of all the rivers of the earth;—"Unto the place from whence the rivers come thither they return again." Nothing could more truly express the fact. The ocean-vapour which has been the sport of winds and currents in the atmosphere knows its true home; for no sooner does it touch the earth as rain

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than, with a seeming instinct and a movement that knows no rest, it hurries down the mountain side and across the plain, or trickles through the mysterious by-paths of the rocks until, collected into brook or river, it plunges once more into its parent ocean.

With the exception of the rain that has fallen directly into the sea, every drop of returning water has gone a long round since it issued from the deep, and by God's goodness it has scattered blessings all the way. Water truly is a blessing to us in every form of its existence. It is a blessing in the ocean, where it diffuses life and the means of living to myriads; as vapour, cooling and refreshing the air at one time, warming and moderating the rigours of climate at another; as cloud, shielding the earth from the sun, checking excessive radiation, and tempering electric influences; as rain, clearing the air from impurity and reviving the thirsty soil; as surface moisture, bringing nourishment to plants and animals; as streams, irrigating and fertilising the land; as springs, infusing health into many a shattered frame; and lastly as rivers, bearing along on their deep currents the commerce that multiplies the comforts of life. Such are a few among the most obvious of its services, but to complete the list would be found an impossibility. In every form and stage God has chosen

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water as His servant to scatter good gifts among His creatures.

Ocean, clouds, rain, and rivers are the elements of a gigantic circulation on which the life of the world depends. The ocean is the mighty heart—the clouds and vapours driven by the wind are the conducting arteries—the minute rain-streamlets are the capillaries vivifying and nourishing every corner of the earth; while the tiny rills, soon swelling into brooks and then into rivers, are the returning veins which empty the water back into the mighty heart. Water is the blood of the earth; where it falls, the surface is living and fruitful; where it is denied, the ground withers into sand. Without the ocean there would be no rain; without rain, no fertile land; without fertile land, no plants;—and without plants no animals.

He gathereth the waters of the sea together, as it were upon an heap; and layeth up the deep as in a treasure-house. Ps. xxxiii.

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THE WINDS OF GOD.

O ye Winds of God, bless ye the Lord; praise Him, and magnify Him for ever.

ONE cannot bestow a thought on the machinery by which the various operations of nature are carried on without perceiving how much is accomplished by means of air and water. In one shape or another these ever busy agents meet us at every turn;—sometimes acting singly, sometimes in combination, but always playing into each other's hands with a perfection which might almost be called intelligence, and which nothing short of infinite wisdom could have devised. Animated by solar heat they form the mightiest engines in nature's workshop—labouring with unerring instinct, fetching and carrying, fertilising, vivifying, and supporting life. They form,

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as it were, the right hand of Providence, and their appointed task is to distribute blessings over the world.

As in water, so in air a continual circulation among the particles is going on; which is not less necessary to maintain the atmosphere itself in a state of purity, than it is to ensure the performance of the various purposes it has to fulfil. These movements constitute currents and winds, and they all originate in a difference in the density of one portion as compared with another. This difference in density may be caused by the presence of vapour, or by the agency of heat, to which may be added the influence of electricity, as is exhibited in the gusts that often suddenly arise in the still, close air which precedes the thunderstorm.

Winds range through an atmosphere encircling our globe to a height of forty-five or fifty miles, and the thickness of this belt in relation to the diameter of the earth has been compared by Maury to the down upon a peach. As air is a fluid, we may consider the atmosphere in its totality as a gaseous ocean, at the bottom of which we living creatures exist and move about. The upper surface of this ocean obeys the law of gravitation, by which all fluids are compelled to maintain their level; and hence, when accumulations of air arise upon its surface from internal disturbance, they must, like

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the waves of the sea, flow down upon the lower levels around, until the equilibrium is restored. The air varies in its density at different heights, according to the pressure of the mass above it. It is greatest, therefore, in low situations, as at the level of the sea, where it weighs fifteen pounds to the square inch, or nearly one ton to the square foot. In ascending, the weight of the aerial column diminishes in a nearly fixed ratio, so that by ascertaining the amount by means of a barometer, the altitude of any given spot may be pretty accurately determined. So rapidly does the weight diminish that, at the top of Mont Blanc, for example, no less than one half of the total mass of the atmosphere is found to have been left below.

One chief cause of the varying weight of the atmosphere at the same level is the greater or less abundance of aqueous vapour present in it. Dry air is 60 per cent. heavier than vapour, and consequently when vapour takes the place of a portion of air the weight of the atmospheric column is diminished. This may be illustrated by filling a tea-cup to the brim with water to represent a column of atmosphere. Our position as mortals upon earth is, of course, at the bottom of the cup where the tea-grounds usually lie; but for the moment we may suppose ourselves looking down upon the top of the atmosphere represented by the surface of the

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full cup. If we now displace a portion of the water by pouring in some lighter fluid, as spirits of wine or ether, the weight of the column will be necessarily diminished; for the teacup, instead of being completely filled as before with the denser fluid, will be partly filled with the lighter fluid also. In exactly the same ratio the weight upon the bottom of the cup, representing the surface of the earth, will be lightened. There can be no permanent accumulation on the top, for the excess of aeriform fluid, in obedience to the law of gravitation, runs down upon the surrounding lower levels, like a sea wave, by which means the same atmospheric height is always maintained. The instrument with which we measure the varying weight of the air is the well-known barometer. A low state of the barometer, therefore, indicates a light or vaporous condition of the atmosphere and a disturbance in the aerial equilibrium; hence, in a general way, rain and wind are to be expected. But in interpreting its announcements many other points have to be taken into account, more especially with regard to the direction of the wind, and the rapidity with which changes are taking place in the height of the mercurial column.

How many there are who habitually pass by the little instrument as it hangs in its corner in the Hall without a thought of gratitude or of admira-

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ration at the wonderful series of adjustments on which its signals are founded. How different it is at sea! There the mariner consults it often and anxiously, as he would a truthful friend who can point out to him betimes when danger threatens. Every movement is analysed, its slightest hints are carefully pondered. Never does a day pass by on which lives are not saved by the warning throbs of this atmospheric pulse. Of late years the barometer has been conspicuously placed in almost every fishing village on the coast, and its signals are explained by the best code of instruction which science can supply.

To be "as fickle as the wind" is one of those proverbial reproaches which are sometimes with scant justice made at nature's expense. In reality, however, the laws of the winds are as fixed as other physical laws, although, from the difficulty of tracing their action in the aerial regions where they rule, we are as yet in the infancy of our knowledge respecting them. That little, however, is of immense service to mankind, and from the attention now given to this department of meteorology we may soon expect to derive from it still greater advantages.

In Ecclesiastes we read,—"The wind goeth toward the south, and turneth about unto the north; it whirleth about continually, and the wind

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returneth again according to his circuits." This is one of those profound expressions in physical science often met with in the sacred volume, which, though greatly in advance of the knowledge prevailing at the time when they were written, have been confirmed with literal exactness by modern investigation. It contains, indeed, the pith of all we know in regard to atmospheric circulation, and it could hardly be more clearly or beautifully stated. The grand circuit of the wind is from the poles to the equator and back again in unceasing rounds; at one time sweeping broadly across the surface of the earth; at another passing in vast volumes in the contrary direction in the upper regions of the atmosphere. It is true these great streams of wind are so often deflected from the straight course to form the most varying local currents, that it might at first sight appear as if all were confusion in the atmosphere. But those local currents, though they retard and complicate, do not ultimately prevent the final result by which the "wind returneth again according to his circuits." The "circuits" are the great wind-channels of nature, and in them we see established in the atmosphere a system very analogous to those polar-equinoctial streams for ever flowing in the ocean.

The power which sets these currents in motion is nature's mainspring—the sun. An enormous

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body of air lying over the surface in equatorial regions, being heated and rarified by the sun, is forced to ascend by the pressure of the adjacent heavier air brought from the north and the south by means of the Trade-winds, and this loss is supplied by air from higher and higher latitudes, until at last the poles themselves are reached. But no sooner has this tendency towards a vacuum been produced at the poles, by the current flowing from it, than an equivalent current begins to be drawn from circumpolar regions to supply the void, and this suction force, acting backwards through lower and lower latitudes, at length arrives at the original fountain, which was the heated air rising up from equatorial regions.

Such, in general language, is the circuit of the wind upon the globe, although locally the greatest variety in the direction of the currents is observed. Aeronauts experience different currents at different heights; and the thunder-cloud may sometimes be seen advancing, under the influence of an upper current, apparently in the teeth of the wind that prevails below. On the Peak of Teneriffe Humboldt found himself exposed to a west wind so violent as almost to prevent him from standing upright, while the people on the plain below were under the mild influence of the north-east Trade.

It has been proved by many interesting obser-

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vations that currents rising from the earth in warm regions sometimes take long courses through the air in a direction contrary to the wind prevailing below. Thus, in various parts of Europe bordering on the Mediterranean, red sand, called sirocco-dust, is occasionally deposited by the south wind. According to popular belief this dust comes from the interior deserts of Africa; but science, aided by the microscope, has proved that sometimes at least it has travelled from regions much more remote. A little of this red substance being submitted to Ehrenberg, he found that it clearly told its own history, being, as it were, labelled with the debris of infusorial animalcules, whose home he knew was in the mud of the Amazon. It appears that in seasons of great drought the river-mud, charged with these minute remains, is first thoroughly desiccated, and then reduced to so fine a powder that it is taken up by the heated air into the higher regions of the atmosphere. The current there joins company with winds bound for the north-east, and carries its freight some thousands of miles across the Atlantic. It next sweeps over the north-west quarter of Africa, and after traversing the Mediterranean deposits its load upon the adjacent lands. In this long journey its route has lain through the upper regions of the atmosphere, passing for a considerable part of the way over the

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Trade-wind which was blowing in exactly the contrary direction.

Let us here briefly notice a few of the principal winds that prevail in different parts of the earth. In tropical countries lying near the ocean, the inhabitants would languish under the stifling air were they not regularly refreshed by the "sea and land breezes." In the West India Islands, more especially, these fannings of nature are described as delicious. Soon after the morning sun begins to glow upon the land, the air, heated as in a furnace, ascends in volumes, and its place is immediately supplied by the cool air that has been resting all the night upon the neighbouring ocean. Hence the "sea-breeze." In the night-time, on the contrary, the temperature of the land falls in its turn, from radiation, below the temperature of the sea, and the direction of the current is reversed. It is now the air over the ocean which is displaced, and the air on the land which rushes off seaward to supply the void. Hence the "land-breeze." In latitudes far beyond the tropics, as on our own coasts, a sea-breeze is often felt in hot weather towards the middle of the day.

The path across the ocean is long and tedious. More than 4000 miles of water lie between the Cape de Verde Islands and Mexico; more than 8000 miles intervene between South America and

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Australia. Unfortunate would it have been for commerce had there been no steadiness in the breezes of those regions—if there had been nothing for the sailor to reckon upon, and if every ship in traversing them had necessarily to become the sport of ever changing winds. Ocean voyages, instead of being performed with a regularity that astonishes, would have been in the highest degree uncertain. The Ruler of the winds has happily ordered it otherwise. Under the Equator there is a narrow belt of calms, broken by fitful storms of rain and thunder. But on both sides beyond there is a broad region reaching to about the 28th degree of latitude where the wind blows regularly all the year round. North of the Line, it comes from the north-east; south of the Line, from the south-east; and thus a favourable breeze is secured for ships sailing across the Atlantic or Pacific in a westerly direction. These are the famous winds called The Trades, in token of the benefits they bring to commerce; and so steadily do they blow, that the sails of a ship may sometimes be set when off the Cape de Verde Islands, without requiring to be shifted until the opposite shore of America is sighted. In the Indian ocean the Trades likewise prevail, but owing to the influence of the great Asian deserts elsewhere considered, the northern Trade is seasonally interrupted and changed into the Monsoon.

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As the Trades help ships across the ocean in one direction only, the question naturally occurs—How do they get back again? Immediately beyond the Trades there is providentially another region of ocean where the winds, though far less regular, have yet a prevailing direction exactly the reverse of that which governs the Trades:—in the northern hemisphere, the set is from the south-west; in the southern, it is from the north-west. Practically, therefore, in whichever direction a ship may be crossing the ocean, the skilful mariner knows that there are tracks in which propitious winds will for the most part be found.

The cause of the Trade-winds has been thus explained. As the earth spins round in diurnal rotation, it is obvious that the land near the equator, being farthest from the axis of movement, must go faster than places situated either to the north or to the south. The former lies, as it were, on the rim of the wheel, while the latter are nearer the axle in proportion as they approach the poles. Hence, at the equator, the surface rotates with a velocity equal to 16 miles per minute; while in latitude 45°, say at Bordeaux or Venice, the velocity does not exceed 11 miles. Accordingly, as the aerial polar current, with the slower rotatory speed of higher latitudes impressed upon it, approaches the tropics, it is unable to keep pace with the increased rotatory

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movement of the surface, and it lags behind, or is "deflected" in a direction which must necessarily be the opposite to that in which the earth is moving. Now the earth moves from west to east. The north polar current, therefore, gradually becomes converted into a north-east Trade, while the south polar current gradually changes into a south-east Trade. If all parts of the earth moved with the same speed, or if there were no rotatory movement at all, the polar currents would be due north and south, or at right angles to the equator; but the eastern impulse which they gradually acquire causes them to move in the diagonal between.

The westerly winds prevailing beyond the Trades are due to causes just the reverse of those now mentioned, being produced by currents of air returning from the equator towards the poles. In commencing its journey the current had acquired, like the surface on which it rested, a velocity of 16 miles per minute in an easterly direction; which merely means that its movement was in equilibrium with that of the earth itself. But when it reached a latitude, say as high as 45°, it found itself in a part of the globe where, from the contraction of the circle, the rotatory pace had been reduced to 11 miles per minute. Instead, therefore, of lagging behind, as in the case of the Trades, the tendency of the momentum it has acquired is to push it on

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towards the east more rapidly than the surface over which it passes. The result is a prevailing south-westerly wind.

In thinking of the benefits derived from these useful winds, it is impossible not to admire the combination of wonderful adjustments by which they are brought about. The very same cosmical conditions which give us the Trades, are made likewise by the All-wise Creator to produce the winds which blow in the opposite direction. The constitution of the atmosphere, the shape of the earth, the rapidity of its axial rotation, the effect of the sun's rays, are all regulated and fitted into each other in such a way as to secure for commerce the advantage of these regional winds.

Although the Trades blow with regularity nearly across the entire Atlantic, there is a strip extending about eighty miles off the coast of Africa where the influence of the north-east Trade is scarcely perceived, forming a remarkable example of the effect of deserts in turning the winds out of what may be considered their natural course. At no great distance in the interior the scorched sands of Sahara are continually sending up vast streams of air into the higher regions of the atmosphere, and hence the cooler air off the coast, instead of being left free to the influences which rule the Trades, is sucked away in the opposite direction—rushing to

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the east, and not to the west—in order to supply the void in the atmosphere of the desert. It is, in reality, a perpetual sea-breeze on a large scale, neutralising and vanquishing the influences which create the Trade. It was, probably, this very breeze which prevented the Portuguese from exploring in a westerly direction, and retarded the discovery of America, for, in pushing towards the south, they hugged the coast of Africa, within safe reach of this wind, and therefore never got within range of the Trade. On the other hand, had there been no Trade, Columbus would never have discovered America. That daring explorer, instead of creeping along the coast kept well out to sea, and soon, therefore, fell in with the Trade. It blew so steadily and carried him so far and so swiftly to the westward that his crew began to fear it was a wind that would never change. The ceaseless breeze seemed hurrying them hopelessly on and on into that mysterious sea which tradition had crowded with superstitious terrors. Fear, as usual, was fast loosening the bands of discipline, and mutiny was on the point of breaking out, when the sight of the eagerly desired land rescued Columbus from his difficulty, and placed a new world in the hitherto unknown void.

The same conditions which produce the Trade-winds on the ocean exist, of course, on land also,

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but the disturbing influences of hills and other circumstances generally prevent them from being so well marked, or even distinguishable at all. In tropical plains of great extent, however, they are sensibly perceived. Thus in South America there is a variable Trade-wind which, sweeping up the level valley of the Amazon, enables vessels to sail against the course of the stream.

The Monsoons of the Indian ocean are likewise great aids to commerce, and both on this account and for other important reasons are charged with blessings to man. They may be described generally as blowing six months in one direction and six months in another, but there is a longer or shorter interval of variable winds and storms interposed between them. From April to October the south-west Monsoon prevails, and ships sailing northwards from the Cape find about the latitude of 12 deg. south a wind which wafts them towards the southern shores of Asia. From October to April the north-east Monsoon has its turn, and speeds the homeward-bound merchantmen across the Indian ocean on their way to England. The south-west Monsoon is due to the same cause which has been pointed out as interrupting the continuity of the Trades off the coast of Africa—the influence of the desert. In the present instance, the work of the Sahara is done by the deserts lying in Central Asia,

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beyond the Himalayas; and the wind while being drawn in towards them, showers down in profusion over the parched plains of Hindostan the refreshing water it has gathered up in the Indian ocean. Some additional observations on these winds will be found in the Chapter which treats of "Showers and Dew."

The hot sand of the Asian desert during the summer half-year attracts the south-west Monsoon, but it has no corresponding action in causing the north-east Monsoon. In winter the sand of the desert partakes of the surrounding comparatively cold temperature, and exerts no special influence on the direction of the wind. The north-east Monsoon in the Indian ocean is, therefore, merely the resumption by the air of that course which it would have taken in summer also but for the disturbing attraction of the desert. It is in reality the north-east Trade, similar to that which prevails in the Atlantic and Pacific. But there are no extensive deserts situated in the southern division of the Indian ocean, and consequently the south-east Trade blows there with comparative regularity all the year round.

It is interesting to remark that the sandy deserts, which one might have been inclined to consider as mere incumbrances on the earth, are thus of high importance in nature's economy.

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They may, indeed, be often regarded as vast suction-pumps, providentially placed at certain stations on the earth, to create winds and help on the transport of moisture to lands that are in want of it. But for the Thibetian deserts there would have been no south-west Monsoon; and without the Monsoon, the fertile plains of Hindostan would have been a waste of sand.

It is at first sight more difficult to understand the advantages of winds like the Khamsin and Harmattan, overpowering the traveller in the desert with their suffocating blasts; or the Sirocco of Italy and Greece, prostrating mind and body under its hot, moist, relaxing breath; or the Typhoon of the China seas; or the hurricane of the West Indies; or the Cyclone which revolves across the ocean. The evil they inflict is obvious, while the good they do is obscure. But that they harmonise with all God's other laws, and that their operation is ultimately beneficial to the world, we may confidently believe. The currents and admixture they promote in the air are of importance to the general welfare, and without doubt outweigh the local inconvenience they produce. It is often observed that great storms are followed by a sensible improvement in the air and by a feeling of increased comfort; hence it may justly be inferred that they are sent to cure something that is going wrong in

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nature's household. We know that the storm sometimes checks the pestilence which human skill fails to subdue. On the banks of the La Plata, in South America, there is a prevailing wind which comes, charged with the germs of intermittent fever, from the marshes lying to the north. The wretched inhabitants droop and sicken and shiver into their graves. Suddenly a hurricane sweeps over the pampas from the cold summits of the Andes in the south west, and in a few days the seeds of the disease are roughly yet effectually expelled. It has, moreover, been remarked that cholera epidemics in this country have usually been attended with great stillness in the atmosphere, by which the operation of causes tending to concentrate the disease was no doubt favoured. Therefore, when we hear the stormy wind howling round our houses, and sweeping through our courts and closes, let us think of it as one of Nature's most efficient sanitary agents, by which she renovates the air that was tainted through stagnation, and scatters the seeds of the pestilence that were growing up for our destruction.

He bringeth the wind out of His treasures. Ps. cxxxv.

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FIRE AND HEAT.

O ye Fire and Heat, bless ye the Lord: praise Him, and magnify Him for ever.

FIRE and Heat enter so essentially into the grand operations of nature that there are few of them which might not fitly be considered in this place. Heat is truly an almost universal "Power of the Lord;" it is the force of forces, the mainspring of movement, and nothing is either too great or too small to be beyond its action. How busily it is ever at work among the natural features invoked in the Hymn! It streams from the sun and the stars, it rules among the planets. Winter and Summer, Climate, Winds, Showers and Dew, Ice and Snow, Cloud and Seas, exist only through its operation; the Green Things upon the earth, Cattle, the Fowls of the air and all that move in the waters depend on it for life. Under its agency the earth itself has been com-

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pounded and shaped. Heat is the great antagonist of the attraction exercised between the particles of matter, which, were they not forced by it into expansion and openness, would condense into one solid mass.

In the affairs of daily life Fire and Heat are absolutely necessary to our welfare. Without them the thousand needful processes of home would be brought to a standstill. Of Fire steam is born—a power which we have subdued and trained to do our work, which fetches and carries, which lifts and lowers for us with more than a giant's strength, which feeds and clothes us, and which wafts us for business or pleasure over land and sea. Fire wins our metals from the ore, and fashions them into a thousand shapes for our convenience. Heat is the strongest of that band of nature's servants which work without ceasing and which know neither fatigue nor slumber.

The great fountain of Fire and Heat is the sun. "There is nothing hid" from it. Its rays, however, are very unequally distributed over the earth, and without some corrective agency there would be an excess of heat at the tropics, and a degree of cold in high latitudes incompatible with life. Now the great equalisers of heat are, as we have seen, air and water and, to a less extent, the crust of the earth itself, whose superficial layers are con-

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tinually transmitting a wave of warmth from the tropics towards the poles.

When we say that, in the ordinary business of life, the source of heat is the combustion of fuel, we may probably be only indicating another shape in which the sun's rays minister to our welfare. It may truly be, as is suggested in the beautiful theory of Professor Tyndall, that the heat given out by bodies in combustion is only the yielding up of those rays of the sun which had for ages been imprisoned within them, and that a piece of coal is only a store of condensed sun-heat, absorbed during the time when it was being formed.

The fuel which offers itself most obviously to the notice of man is wood; and, as it exists abundantly in most countries, it has invariably happened that the faggot preceded the use of the mineral. That the employment of wood should have continued so long in England is easy to understand when we consider the extent of her ancient forests. When Julius Cæsar landed on these coasts the whole country was a vast wood, and a British town meant little more than a patch enclosed and cleared, with a few huts for men and sheds for cattle. But before a thousand years had passed the character of the country had altogether changed, and the Conqueror in carving out his New Forest, so far from merely appropriating an unoccupied woody

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country, pulled down thirty villages and churches, and dispeopled a wide, cultivated district. It must be recollected, however, that this occurred near Winchester, the then capital of the kingdom, where the population was comparatively dense, and the proportion of arable land greatest. Elsewhere forests abounded, and for centuries continued to abound all over England. Alas! where are her old forests now? Of the ninety that were flourishing in the last century barely half a dozen survive. Among these the Conqueror's forest, though shrunk from its old limits, still ranks first in extent, and affords some of the finest "rambling" ground in England. Nor let us be unmindful of Royal Windsor, where scenes of sylvan beauty occur that are unsurpassed on earth. Of the other forests some, we grieve to say, like glorious old Hainault and Epping, are being nibbled and pared out of existence before our eyes, and no voice is raised to save them from ruin. Soon they will exist only in song and story. The loss of others, such as Bere in Hampshire, is less to be regretted. They had served their time, and fell naturally before the plough in their old age, after centuries of usefulness. With forests like these we part reluctantly, but the demands of agriculture must be satisfied.

In the olden time, as now, abundance of fuel carried with it the principal manufactures, and, for

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obvious reasons, the smelting of iron more especially. This most useful of all metals, like nearly everything else that is serviceable to man, has been distributed very widely over the earth. It is a constituent of nearly every soil and rock, it can often be traced in water and even in air, and it also exists in the tissues of most animals and vegetables. The great storehouse, however, from which we derive our supplies is iron-ore, in which the metal is usually combined with oxygen or with carbonic acid, and in no instance is iron found naturally in a pure state except when it exists in the meteoric form. In the various processes for reducing it to its metallic condition, Fire, aided by a certain amount of carbon, and with a portion of limestone as a flux, is the chief agent employed. Wherever, therefore, iron-ore and fuel are found near together there the manufacture establishes itself, and it is to this circumstance more especially that England owes her preeminence in the production of this metal.

Before the days of coal, iron was smelted with wood; and as Sussex and the forest of Dean not only contained the ore but were abundantly provided with timber, they became the first seats of the English iron manufacture. In process of time, as the forests were cut down, the works were transferred from Sussex to the iron fields of the north.

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and west, where the furnaces could be heated and the ore smelted by coal found abundantly on the spot. And in proportion as, in these days, the use of iron has expanded and driven other competing substances almost out of the field, an ever bountiful Providence has led man to new stores of the metal practically inexhaustible. The most recently discovered field in Yorkshire has an extent of several hundred square miles, and alone would be sufficient to meet the present enormous demand for many centuries to come. In the year 1863 considerably more than nine millions of tons of iron were produced in the United Kingdom, at the cost of a consumption of coals equal to two millions of tons. Most of the other valuable metals obtained in this country are also won by the agency of Fire and Heat, from which may be estimated the services performed by them in a single department only. If we add to the operations of metallurgy the labours of the coal-pit, we have a branch of industry in the prosecution of which immense numbers of our population obtain the means of daily support.

Coal is the most valuable fuel in existence. It is, however, a singular illustration of the slowness with which useful discoveries are made, even under favourable circumstances, that some thousands of years should have rolled over the world before the superiority of coal over wood as a heat-producer

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came to be generally recognised. The inferiority of wood is in great measure due to the quantity of water which it contains; as the water, in passing off in a state of vapour, absorbs much heat which would otherwise have become sensible. Hence, also, the advantage of keeping wood that is to be used for fuel until it becomes dry. Coal was unknown to the Greeks and Romans; and although cinders have been found in the excavations at Uriconium, it is doubtful if it began to be burnt as fuel in England until long after the Romans had left. It is probable, however, that the black lumps found here and there upon the surface, or in digging for wells, or in other accidental ways, were known to be combustible long before the increase of population and the dwindling away of the forests forced men, as it were, to the regular use of coal. Like many other valuable discoveries, it had for centuries to contend against the prejudices of numerous enemies, and many evil things were said about it. In the 13th and 14th centuries it was the fashion to petition against it as a nuisance, just as we now protest against noxious exhalations from chymical works. So prejudicial to health were coals considered, that they were not tolerated in London, or even in its vicinity, under the severest penalty, and a smith who used them in his forge instead of wood was in danger of being sent to prison. Not

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until towards the year 1400 did the use of coal become general in the metropolis, and, even after that, wood continued to be the fuel of the country until the time of Charles I.

Although we speak of coal as a mineral, it is nevertheless of vegetable origin. Every particle of it, except that earthy residuum which in good coal is very small in amount, once formed part of a living plant. There is a kind called Lignite which often consists of little else than fossilized trees; but the more perfect varieties may be considered as having their origin in peat-producing plants—chiefly mosses—which have been in the course of time compressed and metamorphosed into coal. All traces of moss structure have for the most part been obliterated. But in the same way as fragments of wood have been abundantly preserved in our bogs, so in the coal strata—those bogs of ancient days—relics of the trees which once flourished beside the peat are frequently found, likewise converted into coal, and in them the original structure of the wood, even to its microscopic details, is often beautifully displayed.

The quantity of carbon anciently extracted from the air, fixed in the tissues of plants, and then gradually converted into coal, is enormous. The area of all the known coal-fields in the world is computed to be 220,000 square miles—more than

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the whole surface of France—which, allowing a moderate average thickness of 20 feet, would be equal to a solid cube nearly 10 miles in dimension. As Professor Rogers observes, it would form "a square plateau 100 miles wide at the base, and more than 500 feet in height." The proportion of our British lump of coal "would be a cube of a little more than three miles in diameter."

Within the last century the consumption of coals has increased to an extent never dreamt of by our forefathers. In round numbers we are using up about 100 millions of tons annually. Who can enumerate or even conceive the sum of enjoyment which is daily extracted from this huge, black heap? How many millions of hearths are made cheery by its glow, how many palaces and cottages are filled by it with comfort-bringing heat. What countless numbers of things of use or beauty are manufactured by its aid for our enjoyment. For how many mouths does it not prepare daily food. What great work is there which it does not help on? From its dull looking fragments is distilled the gas which brightens up our houses and our streets. To coals we owe steam, and what is there in these days which we do not owe to steam? Steam gives us muscles stronger than iron, and yet finer in action than the most delicate hand. With the tools which man's ingenuity has provided, it

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labours incessantly without rest, and performs its task with a certainty and exactness with which nothing human can compete. Be the work rough or smooth, coarse or fine, steam adjusts itself to it with matchless skill. Steam wields the ponderous hammer as if it were no heavier than a feather, and can with equal ease crush an iron beam or crack a nut-shell. The amount of labour saved and the physical strength thus gifted to man are enormous. Give a good steam engine a bushel of coals, and it will lift a weight of 125 million lbs. one foot from the ground! Every three tons of coals are "the convertible equivalent of one man's life-long muscular activity." The 15 millions of tons annually consumed in this country in the production of mechanical force is equal to 20 millions of horses, or to a band of 100 millions of men! The power thus acquired is turned at will into an infinity of channels, all working in the service of man.

By the beneficent design of Providence coal-mines are widely distributed over the earth, and our own islands, more especially, have been blessed with an abundance that calls for thankfulness. The aggregate extent of our coal-fields amounts to no less than five thousand four hundred square miles. Yet when we consider our enormous consumption and reckless waste, we wonder not that thoughtful minds should look forward with anxiety to the

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possible advent of a day when our pits shall have become exhausted. That day may be distant; still it is confessedly not so very remote as to lie beyond the range of present interest. In a question of this nature, where the difficulty of obtaining exact data is so great, it is but natural that opinions should widely differ; but, on the whole, we may accept with some confidence the assurance that the stock of coal yet on hand will suffice for at least a thousand years to come.

Within the last few years the bounteous earth has yielded up to man another source of light and heat in Petroleum, which has already assumed commercially the highest importance. It was observed during the Burmese war that rock-oil was much used by the natives for ordinary illumination; and, when peace was concluded, it began to be imported into this country. It is now obtained in considerable quantities from other quarters also, especially from the districts on the lower Danube. But all these sources are thrown into the shade by the oil-wells of North America. In 1863 the quantity raised from the Pennsylvanian springs alone was 40 millions of gallons, while that from Canada amounted to 250,000 gallons; and since then the produce has been steadily increasing. In this country, after purification, Petroleum is much used as oil for lamps; and paraffine or mineral-wax

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candles are also extensively manufactured from it. Large quantities of oil of an excellent quality are likewise obtained from the shale in contiguity with the coal measures, a substance which only a year or two ago was deemed refuse of no value. A single ton of the Torbanehill mineral is capable of producing 120 gallons of oil. Recent trials also indicate that Petroleum is well adapted as fuel for marine engines, as it produces a larger quantity of steam in proportion to its bulk than can be obtained from coal.

How much it seems to be a matter of course to see the fire burning brightly on a cold winter night. We enjoy the comfort it diffuses, and, perhaps, we congratulate ourselves that coals are so easy to be had. But how rarely do we carry our thoughts a step farther, or reflect upon the extraordinary nature of the blessing. Countless ages ago our Father anticipated our wants and provided for their relief. The coal we burn is, so to speak, manufactured, and the manufacture was established thousands of years ago, when God caused to grow the mosses and other little plants which by slow accumulation became masses of peat. The raw material then went through other long processes. It was compressed and solidified and chymical changes were wrought in it. Then, lastly, the precious coal was stowed away carefully in the cellars of the earth on

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purpose that we might be made warm and happy by the "Fire and Heat" which from the beginning of its creation it was designed to supply.

In looking back at the history of fuel, the mind that loves to trace design in the ways of Providence cannot fail to be struck by the wise economy with which the treasures of the earth have been gradually unlocked, and one supply after another has been granted as the necessity for it seemed to arise. In the old time, when forests were everywhere and population was sparse, wood was the fuel invariably used. So long as manufactures were in their infancy the primeval forest answered all demands made on it. But in process of time population multiplied, and it was necessary to strip the land of trees on purpose that it might be sown with corn. Wood then became less abundant. New sources of heat were, therefore, absolutely needed; so God taught man the use of coal, which had previously been esteemed mere rubbish. Again, as oil from the old supplies became more scarce, and the demand for street and house-lighting increased, the gas imprisoned in the coal was discovered, and our power of illumination was thereby almost indefinitely augmented. To economise nature's resources vegetable wax and various vegetable oils have also recently been much employed. Lastly Petroleum was discovered, and the oil fountains of

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the earth were made to flow for our use. There is still the probability that some of the metals may be made available for illumination, and that before many years are over our means may be still further economised by a more frequent application of the electric light. Have we now arrived, it may be asked, at the end of the long list of nature's resources, and are we to believe that when the last coal-pit has been worked out, and the last oil-spring emptied, we shall be left to perish with cold, or at least to live miserably, deprived of the comforts which for so many ages have been placed within our reach? With the firmest conviction we repel such a thought. It is utterly repugnant to our knowledge of the merciful ways of Providence. Our Father enriches but never impoverishes the earth, and the intelligence of His creatures is ever made the means by which new gifts are discovered. The essential constituents of fuel are only two—carbon and hydrogen. To them wood, coal, and every other kind of fuel owe their heating virtue. Now the world is literally packed with carbon and hydrogen, and it is not in the power of man to dissipate these elements of supply. Carbon is the staple out of which animals and vegetables are built up, it is a constituent of many rocks and of every soil, and it pervades the air. Hydrogen is even more abundant. It forms one ninth part by weight of every drop of

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water on the globe, and therefore it may be said that rivers and lakes and the ocean itself are vast reservoirs of latent fire. Of the two constituents of water, one—oxygen—is an admirable promoter of combustion, and the other—hydrogen—burns under ordinary circumstances with more heat than coal, while by the skilful admixture of the two a temperature of the highest intensity is produced. We do not attempt in these conjectural hints to indicate the way in which such materials will be made available, and the want of coal supplied, but only to point out that sources of "Fire and Heat" exist everywhere around us, and that, when need comes, God will inspire His children with wisdom to turn them to account. In looking into the future, therefore, let us dismiss anxiety from our minds, in the firm conviction that nature's resources are boundless, and that, if the world be still existent in those far off days, God will not forsake the race for whom His providence has done, and daily does so much.

O put your trust in Him alway.—Ps. lxii.

END OF VOLUME I.

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